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Publication date:
2010

Document Version
Publisher's PDF, also known as Version of record

The Economic Impacts of Climate Change in Montenegro: A First Look

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Title: ***The Economic Impacts of Climate Change in Montenegro: A First Look***

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EXECUTIVE SUMMARY, MAIN CONCLUSIONS AND RECOMMENDATIONS

Summary

This report has five objectives, as follows:

- To identify the data and state-of-the-art models and methods needed to estimate the economic impacts of climate change and the benefits and costs of adaptation in agriculture and forests, tourism, water resources and human health in Montenegro,
- To assess the extent of the capacity in-country to develop and apply these data, models and methods to Montenegro's situation,
- To use existing data, models and methods available in Montenegro to make some highly preliminary estimates of the economic value of the physical impacts that were identified in the First National Communication, and finally
- To suggest ways in which the existing analytical and institutional capacity to estimate the economic impacts of climate change and the benefits and costs of adaptation in Montenegro can be improved.

The Introduction to this study (Chapter 2) describes the underlying theory for estimating the economic impacts of climate change. Climate change, in one way or another, affects the quantity and quality of environmental services that humans use both to produce goods and services, for lack of a better term, to "enjoy life". That is how these physical impacts make their way into markets for goods and services and every day life. In markets, climate change influences the production and market prices of goods and services in the sectors affected directly by climate change. In modern economies markets are linked together by inter-industry flows of both goods and services and the money exchanged for these goods and services. These inter-industry flows act as a conveyor belt for climate change impacts, spreading them potentially throughout the whole economy.

Accordingly, this study identifies two types of impacts of climate change. The first are welfare impacts and the second are impacts on indicators of national economic activity. Welfare impacts measure the economic gains and losses that consumers, producers and investors experience directly as a result of climate-induced shifts in market supply and demand curves. These welfare effects for these three groups have a similar economic meaning and the theoretical basis for measuring them and adding them up (and not adding them up) is well established. These economic impacts are known as "climate change damages". Adaptation can reduce some of these damages at some cost. The net reduction in climate change damages due to adaptation is called the "net benefits of adaptation". Finally, the climate change damages that are left over are called the "imposed damages of climate change".

The economic impacts of climate change on indicators of national economic activity are different. They measure changes in such things as gross national product, consumption spending, investment and government investment. These impacts also include measures of labor force activity, like employment and unemployment, and income transfers between countries. In some cases, national income accounting systems provide the rules for adding up some, but not all, of these impacts. Apart from that, these impacts – even if they are measured in monetary terms – should not be added to the value of welfare impacts, although both represent important information for decision makers in the public and private sectors to help them cope with climate change.

The four chapters after the Introduction focus on the following economic sectors or impact categories in Montenegro:

- Chapter 3: Agriculture and forests, which are joined, because they share a common land base,
- Chapter 4: Tourism,
- Chapter 5: Water resources, which cuts across many different market sectors in the economy, and
- Chapter 6: Human health, which is limited in its coverage.

Each chapter outlines the main methodological approaches, types of models and data bases that are needed to make comprehensive estimates of climate change damages, which is different in every sector and impact category. It also attempts to outline the current status of the existing capacity to develop these models and use them to estimate climate change damages in Montenegro. In most cases, this capacity is extremely limited or non-existent. It is also possible that some of the capacity to do this does exist, but is hard to locate. Each chapter also contains short- and long term- recommendations for developing this capacity in the future in the different economic sectors and impact categories.

The study uses what we call a "no regrets" approach to capacity building. This means that the models, methods and data needed to estimate the physical and economic impacts of climate change and to make decisions in the public and private sectors about how to "best" avoid these impacts through adaptation can, in many cases, be used to making planning and management decisions related to economic development and environmental protection. In other words, the rationale for building these models and developing new data bases is to help Montenegro develop its economy in a wise way that benefits both Montenegrins and their natural environment and ecosystems. The valuable role they can perform to help cope with climate change is an added benefit.

The results of the capacity building assessments in each chapter will be addressed in the last part of this chapter, under the heading of "conclusions and recommendations". The rest of this summary is devoted to the quantitative analyses in each sector to make selected estimates of climate change damages due to specific impacts on specific sub-sectors or locations in Montenegro.

Simply because Montenegro lacks state-of-the-art models to estimate the economic impacts of climate change does not mean that is impossible to make some preliminary estimates of these impacts. In fact, these types of preliminary estimates, which rely on existing data and methods as well as a number of key assumptions to replace what is missing, can be very useful in the early stages of formulating climate and development policy. In particular, this "limited information" approach can sometimes identify the range and scope of economic impacts; it can identify impacts of importance that might not be obvious at first; and it can tell you something what assumptions and data may be important and what are not. All of this information – while not perfect – is probably better than nothing.

In all, this study made a preliminary estimate of climate change damages in the following areas[4]:

1. Agriculture and forests: the climatic impacts of reductions in maize yields, nationally, on gross farm revenues using information from a crop yield simulation study in Croatia.
2. Agriculture and forests: the climatic impacts of increased crop water demand on the cost of pumping and distributing additional irrigation water to crops on existing and new irrigated land.

4 One additional estimate was undertaken: to estimate the effects of climatically-induced reductions in beech tree growth on rotation ages and land values for even age stands of beech in Montenegro. It was unsuccessful (due to unreasonable results) due to poor data.

3. Tourism and recreation: the climatic impacts of increased temperatures on the visitation by and expenditures of international and domestic tourist in Montenegro using partial information from the Hamburg Tourist Model (HTM).
4. Tourism and recreation: the climatic impacts of increased temperatures on the visitation by, and expenditures of, international and domestic tourist in Montenegro using partial information from the PESETA project methodology for estimating tourism impacts.
5. Water Resources: the climatic impacts of reduced runoff on the gross revenues from the sale of electricity from the Mratinje Dam hydroelectric plant on the Piva River.
6. Health: the climatic impacts of higher temperatures on the economic value of additional lives lost due heat-related mortality in Montenegro.

A summary of the results for all six case studies are shown below in Table 1. The results are the undiscounted average annual value of climate change damages for each case study under the Climate Change Scenarios A1B Near Future (2001-2030) A1B Far Future (2071-2100) and A2 Far Future (2071-2100). In some cases not enough information was available to estimate the results for all three scenarios and in the case of the health assessment only information from the B2 NF and FF scenarios was available. In these cases, information from the climate scenarios and physical economic impact estimates were used to interpolate and fill "missing values".

Since these are the first such estimates of climate change damages in Montenegro and because there are so few similar estimates for other Balkan countries, it is a bit difficult to put them in perspective without much more information about the individual sectors. Nevertheless, these results do raise a number of important research and policy issues. The average annual climate change damages due to reduced maize yields are small because little maize is produced. However, these damages would increase if the livestock sector is expanded significantly based on future development plans and locally grown maize is used to fatten cattle in feed lots. This would involve a large structural change in the agricultural sector. The average annual damages due to increases in irrigated crop water use were higher than expected for relatively small amounts of land. This could be a cause for future concern, if the actual development of newly irrigated lands is more aggressive than expected. This would also depend on the effects of climate change on the competitiveness of domestic vs. imported fruit, grapes and wine in local markets and international markets. So, in both agricultural case studies better models – agricultural sector models, to be specific – are needed to take into account those factors.

Table 1 Preliminary Estimates of Average Annual Climate Change Damages Due to Simulated Climate Changes for Selected Case Studies in Different Sectors in Montenegro (millions of €/year)

Nature of Impact	Climate Change Scenario		
	A1B NF	A1B FF	A2 FF
Reduced Maize Yields[1]	Reduction in Gross Revenues from Maize Sales		
	0.016	0.043	0.81
Increased Crop Water Needs[2]	Increased Costs of Pumping and Distributing Additional Water to Irrigate Crops on Current and New Land		
	0.074	4.33	4.41
Increased Temperature[3]	Reductions in Tourists Expenditures (HTM analysis)		
	34.20	68.35	85.45
Increased Temperature[4]	Reductions in Tourists Expenditures (PESETA analysis)		
	(13.90)[5]	33.20	33.50
Reductions in Runoff	Reduction Gross Revenues from Electricity Sales from Mratinje Dam		
	6.60	12.80	--
Increases in Temperature[6]	Value of Additional Lives Lost due to Heat-Related Mortality		
	--	--	4.60 to 85.20

[1] Yield reductions are in % terms, not by scenario. Assumed domestic corn price: 60€/MT.
[2] All irrigated lands (new and planned) at 0.15€/Kwh.
[3] Base Case Ave. Annual Temp 16 deg C Base Case tourism levels and expenditures are current average.
[4]Base Case tourism levels and expenditures are current average.
[5] This estimate is in brackets because it is actually a benefit of climate change and not a cost.
[6] Range reflects valuation method (VOLY-VSL)

The estimated climate change damages due to reductions in tourists are reasonably large compared to existing expenditures by tourists. The differences between the two sets of estimates in this sector illustrate a common phenomenon in economics, namely that different models have different sensitivities to input assumptions and data. The estimate obtained by the PESETA-based approach for the A1B NF scenario is actually believable: short-term climate change may be a good thing for tourism, but eventually – if these models are right – average and peak temperatures will become so high that tourists, in the summer time at least, will shift their beach visits northward.

The climate change damages associated with reductions in runoff on the Piva River are also relatively large, but the methodology was fairly crude. This also points to the fact that better models and data are needed to confirm and improve upon these estimates in this, as well as other, sectors. The future of Montenegro's hydroelectric power ambitions could be dramatically affected by climate change and planners need to look at including the impacts of climate change on runoff and electricity demand into current and future development plans.

The last estimate of climate change damages in the health sector probably looks like a big number to people who are not familiar with value of life assessments. However, compared to other EU and some Balkan countries included in the PESETA health care analysis for the EU, the estimated climate change damages presented in Table 1 are fairly small and based on relatively small numbers of additional deaths due to higher temperatures. Montenegrins apparently are already acclimatized to cope with large variations in peak summer-time temperatures.

The estimates of average annual climate change damages summarized in Table 1 have a number of limitations:

- The methodologies are preliminary and not very sophisticated, in most cases based on very limited data and strong assumptions that were required to conduct the analysis, but may not be true,
- The results are not comprehensive. They are case studies.
- The measures used in each case study require somewhat strong assumptions to qualify as valid damage estimates, based on welfare losses and gains, in the field of economics. As such, the temptation to add them up should be resisted.
- These estimates of climate change damages do not include welfare losses by consumers due to price changes, caused indirectly by climate change.
- The estimates in these cases should not be misinterpreted as impacts on national economic activity, such as GDP. These types of economic impacts were not estimated because no macroeconomic model of the Montenegrin economy could be located.

Finally, the limitations of these results make a strong case for improving the capacity to develop better data and models. This will be the focus of the final section of this chapter, covering conclusions and recommendations.

Conclusions and Recommendations

Chapters 3 through 6 all contain a concluding section that presents the main findings with respect to the status of the capacity to estimate the economic impacts of climate change and use this information to make public policy or to plan and manage public and private sector activities. The section also provides recommendations about how to address these "capacity gaps" in the short- and long-term.

This section combines these findings and recommendations with major conclusions that flow from the case studies into a shorter list that highlights the most important results of this study.

Main Conclusions

1. **Need for Macroeconomic Model**. An important analytical gap that was found especially limiting in the case studies of tourism was the apparent lack of a macroeconomic model for Montenegro, both in-country and in the larger institutional modeling community.
2. **Value of Preliminary Estimates of Climate Change Damages**. This study has demonstrated that, even in the absence of more sophisticated data and better models, preliminary estimates of climate change damages – as in the Case Studies – can provide useful information about the economic impacts of climate change to guide decisions both about development policy and building the capacity to improve the analytical capacity about economic development and options for coping with climate change.
3. **Need for Better Models and Data.** This study set out the state-of-the-art in modeling climate change damages in all of the case study sectors. There are significant gaps in both models and data in every sector we examined in both simulating the physical impacts of climate change and translating these impacts into measures of climate change damages using integrated environmental-economic sector models.

4. **Priorities for Capacity Building.** Based on the results of the case studies and the development plans of the country, the priorities for developing these type of models would appear to be as follows:
   a. **Highest priority:**
      i. Aggregate tourism participation models for the country as a whole, and
      ii. Rainfall runoff and hydro-economic models for basins targeted for future hydroelectric development.
   b. **Lower priority**
      iii. Stand management models (and support data) for forests that include growth models to simulate the impacts of climate change and forest disturbances on the growth of managed forest types,
      iv. Vegetation models to simulate forest growth and development in unmanaged ecosystems,
      v. Crop-yield models for important crops in the country, and
      vi. A dynamic, two sector model of the agriculture and forest sector, for example through integration with EUFASOM.
      vii. Site-specific recreation demand models to project the effects of development policies and climate change on visitation on recreation welfare values at selected key sites, valued for environmental preservation and/or recreation purposes.
   c. **Uncertain priority:**
      viii. Epidemiology models for simulating impacts of climate change on mortality and morbidity from a variety of sources, including: temperature-related mortality and morbidity, water and food-borne diseases, vector-born diseases, extreme events-related health impacts.

Main Recommendations

1. **Macro-Economic Model.** A computable general equilibrium (CGE) model should be developed for Montenegro. However, it is important that the model be able to address Montenegrin development issues, specifically by requiring that the "entry points" into each sector can realistically represent impacts that are related to Montenegro's development plans and the impacts of climate change. These models can be developed through contracts with multi- and by-lateral institutions, involving international and regional centers of expertise in this field.
2. **Data Collection Efforts.** The case studies revealed data deficiencies in all of the sectors. An effort to make a case steady of the impacts of climate change ran afoul of a lack of growth data for managed forests. However, an ambitious project is underway to develop new forest inventory estimates and this may also be helpful to calibrate forest growth and vegetation models. Building new data bases, where old ones have collapsed is going on in many sectors, and the prime recommendation of this study is for responsible agencies to see that this information is also helpful for conducting climate-change related assessments.
3. **Model Development.** It is recommended that the physical impact models and related integrated environmental-economic assessment models identified in Conclusion 4 be developed over a period of five to ten years in line with the priorities identified in that conclusion.
4. **Coordination of Data Collection and Model Development.** It is recommended that data collection efforts by the government and model development efforts be coordinated.

5. **The Need for Developing in-Country Capacity.** Developing the capacity to build and implement models that can be useful for planning and managing natural resources and estimating the physical and economic impacts of climate change should focus on the long-run development of human capital in Montenegro and Montenegrin institutions. This is harder said than done because immediate research needs are always satisfied more quickly by importing human capital in the form of foreign consultants. One way to try to ensure that the capacity is transferred to Montenegro is through training for and collaboration of Montenegrin experts in sector-related fields with modeling centers of excellence throughout the EU and Balkans backed by multi- and bilateral funding. Another option is to program the development of EU-wide models such as FASOM with the training of and collaboration by Montenegrin experts in cooperation with the European model developers through exchanges, Ph.D degrees from the developing academic institutions and post-doctoral training.

1. INTRODUCTION

Montenegro has recently completed its first National Communication to the United Nations Framework Convention on Climate Change (Ministry of Spatial Planning and Environmental Protection of Montenegro – MSPEP, 2010: Draft). This study identifies potential climate change impacts in a number of sectors and, in some cases, presents preliminary estimates of the magnitude of these impacts under several different climate scenarios. However, one thing the study lacks is an in-depth discussion of how these physical impacts might affect not only the economic welfare of producers, investors and consumers in different economic sectors, but also how they might affect indicators of economic activity such as gross domestic product, personal consumption expenditures, private investment and government spending. This report was envisioned by UNDP as a way of filling in these gaps in the National Communication and to pave the way for more in depth examinations of economic impacts.

However, previous experience and current practice by economists suggests that this type of assessment is difficult enough in developed countries such as the United States (US) and the European Union,[5] and even more difficult for countries like Montenegro that have been buffeted by several decades of sudden political changes and economic upheavals[6]. During this period, the data and models and the analytical and institutional capacity to plan and manage a centrally-planed economy were swept away by the disintegration of Yugoslavia. Sectors in which these data and models had played an important role in natural resource planning and management were "privatized". As a result, the effective role of government to perform many key functions in some sectors ceased to exist in practical terms and was not replaced by the private sector. Following the disintegration of Yugoslavia, Montenegro was also subject to international sanctions, directed at Serbia's foreign policy. This had the effect of limiting the flow of new ideas, new educational and training opportunities, and new development funding, from the West into Montenegro. As a result, the analytical capacity to develop and implement natural resource and environmental planning and management tools and the institutional capacity to use these results in planning and management decisions in the public and private sector was not developed in any systematic way.

Montenegro's independence has created many challenges for development and economic growth. At the same time, however, some of the gains that were made between 1989 and 2006 in terms of the recovery of the capacity to plan and manage natural resources remained in Serbia when the two nations finally split apart.

In the past 4 years, the government of Montenegro has launched a set of policy initiatives that target important sectors for economic development, while trying to balance environmental and economic objectives. In this process, there is a strong need for Montenegro to redevelop the analytical and institutional capacity to manage its natural resources in new ways. Accordingly, the government has also launched a number of initiatives in the context of its development policy to do just this. The national office of UNDP supports this by finding funds to enable capacity building efforts in many areas, including climate change.

In that general context, this study has been funded by UNDP to accomplish four main objectives:

5 For the US, see Mendelsohn and Neumann (Eds.). 1999. *The Impact of Climate Change on the United States Economy*. Cambridge University Press and for the EU Ciscar et al. *Climate Change Impacts in Europe. Final Report of the PESETA Research Project*. Joint Research Centre, Seville.

6 See, for example, the Croatian Human Development Report (HDR): UNDP Croatia. 2009. *A Climate for Change* that focused on the impacts of climate change, including a limited assessment of economic impacts.

- To identify the data and state-of-the-art models and methods needed to estimate the economic impacts of climate change and the benefits and costs of adaptation in agriculture and forests, tourism, water resources and human health in Montenegro,
- To assess the extent of the capacity in-country to develop and apply these data, models and methods to Montenegro's situation,
- To use existing data, models and methods available in Montenegro to make some highly preliminary estimates of the economic value of the physical impacts that were identified in the First National Communication, and finally
- To suggest ways in which the existing analytical and institutional capacity to estimate the economic impacts of climate change and the benefits and costs of adaptation in Montenegro can be improved.

This study is composed of seven chapters. After the Introduction, here in Chapter 1, Chapter 2 defines what is meant by "economic impacts" and gives a brief explanation of how these impacts are estimated using integrated environmental-economic assessment models and macroeconomic models. It also provides several justifications for making very preliminary calculations of the economic value of climate change damages using existing data and methods that are available in Montenegro. Finally, it explains how the concept of "no regrets" can be used to identify models and methods that not only estimate the economic impacts of climate change, but also are more generally useful as planning and management tools in natural resource sectors.

Chapters 3 through 6 are devoted to individual sectors or impact areas:

- Chapter 3: Agriculture and Forestry
- Chapter 4: Tourism and Recreation
- Chapter 5: Water Resources
- Chapter 6: Human Health (Impacts on temperature-related mortality)

Each sector chapter contains the following subsections:

- Identification of the potential physical impacts of climate change,
- Identification and explanation of the data and state-of-the-art models and methods for estimating the economic impacts of climate change,
- Identification of the current capacity in Montenegro to implement these data, models and methods, which in most cases is limited,
- Identification and implementation of an approach for making preliminary estimates of selected economic impacts, and
- Concluding suggestions about how to improve the current analytical and institutional capacity to estimate the economic impacts of climate change and use this information to inform public policy decisions and private sector planning and management in natural resource industries.

1.

2. THE ECONOMICS OF CLIMATE CHANGE

2.1. Background and Objectives

2.1.1. Background

The term "economic impacts of climate change" can mean different things to different people and how to go about estimating the economic impacts of climate change can be even more confusing. But one thing is clear, decision makers at all levels of government and in the private sector will need, and are already asking for, information about the economic impacts of climate change and the costs and benefits of adapting to it.

A fairly common misconception about estimating the economic impacts of climate change is that this is relatively easy to do, compared to simulating the effects of increases in greenhouse gas emissions on the global and regional climates or the effects of regional changes in climate on the natural and man-made environment and on animals and humans. Attitudes like this have been fairly pervasive not just with respect to the role of economics in climate change assessments, but also about the role of economics in helping to solve problems related to all sorts of environmental pollution. This attitude, in turn, has led program planners in research fields related to environmental pollutants and climate change to think of economic analysis as an "add on" task that can be accomplished after all the "hard work" in the natural and physical sciences is completed. The result of this thinking has been both an under-utilization of the full potential of economic analysis in research related to environmental problems and a growing realization that this has been the case and needs to be set right.

This newer attitude is reflected in the growing body of work that involves integrating environmental and economic analysis in so called "integrated environmental-economic assessments" of climate change. It also has contributed to the co-operation between natural and physical scientists and economists in developing economic models that link natural and physical processes with economic market principles. This new generation of integrated environmental-economic models has the ability to translate the physical impacts of climate changed into monetary measures of these impacts, into impacts on sector- and macro-level measures of economic activity, income, employment, etc., and into the benefits and costs of reducing the physical and economic damages of climate change through adaptation.

2.1.2. Objectives

This chapter is about how economists define and estimate "the economic impacts of climate change". It is also about the importance of identifying and building the capacity to simulate and estimate these impacts and how to build this capacity in a way that will benefit not only climate change policy-making, but also policy- and decision-making related to natural resources planning and management.

This chapter does five things. First, it defines what economists mean by economic impacts. Second, it describes how climate change impacts can affect economic markets, making it possible to value some – but not all – of the physical impacts of climate change. Third, it describes how models from the natural and physical sciences can be joined with economic models to simulate the effects of climate change on markets. Fourth, it describes some short-cut approaches, such as those used in this study, to make preliminary estimates of these economic impacts and suggests how these estimates can be helpful. Finally, it describes a way of building analytical and institutional capacity based on the principle of "no regrets" that can be used to address gaps in the analytical capacity to plan and manage economic development in many different sectors of the economy, while at the same time being helpful for making decisions about mitigating greenhouse gas emissions and adapting to climate change.

2.2. Brief Overview of the Economics of Climate Change

The underlying theory for valuing the economic impacts of climate change in specific sectors is the same as for valuing the damages of almost any environmental pollutant and has been widely applied for many air and water pollutants in numerous settings (Adams et al. 1985; Adams et al. 1986; Smith and Desvouges 1985; Carson and Mitchell 2004). What makes climate change different, for policy purposes, from conventional air pollutants is that a ton of greenhouse gas (GHG) emitted from any location will have roughly the same forcing effect on global and regional climates as from any other location. However, the global nature of the impacts created by GHG-induced climate change is only relevant for mitigating GHG-induced climate change impacts. It does not affect the valuation of the climate change damages at specific location or the valuation of global damages which is the sum of all the local damages. Moreover, adaptation measures only yield local benefits; however, to the extent that adaptation actions are contingent on climate change, their benefits and costs are influenced by successful mitigation of GHGs.

Changes in climate, no matter what the cause, have the potential to affect the goods and services provided by the natural environment within many market sectors. For example, changes in temperature and precipitation and a host of other meteorological variables influence the growth and development of commercial crops, the amount of runoff that is available for use from surface and groundwater sources by humans, animals, and industry. Changes in climate can also directly and indirectly affect the flows of environmental services that attract tourists to specific locations to engage in certain forms of recreation for their own enjoyment. You can't ski if there is no snow and going to the beach is not much fun when the air temperature is 40^0 C. plus and the water temperature is not far behind. Nor can you enjoy hearing the birds sing if they are gone. And, if climate change causes sea levels to rise, beaches can be lost and valuable beachfront property inundated. These are just some of the examples of how climate change disrupts the flow of environmental services in a few different sectors.

While the physical damages of climate change are easy to explain and understand (but often hard to measure), valuing these damages in monetary terms is less easy to understand. We have already given some examples of how market goods (crops, drinking water, goods and services purchased by tourists, etc.) are linked to climate change. In some cases, climate change can affect the demand for a market good: it gets hotter and crops and humans need more water to survive. In others, it can affect the supply of a market good: crop yields can fall, water supply can be diminished, and beach opportunities for recreation may be altered. And in some cases, climate change can simultaneously influence both the supply and demand for a market good: when it gets hotter and drier society generally needs more water, but there is less of it.

For reasons that only economists can explain with diagrams and/or mathematics (see Figure 2.1), the effects of climate change on the supply and demand of market goods has the potential to change both the quantities of some market goods and services that are produced and consumed and the market prices of these goods. In many – but not all – cases, theses adverse climate change impacts will be characterized by reductions in the production and consumption of some market goods and increases in their prices. For example, a warmer drier climate could reduce domestic crop production and increase domestic food prices (depending on the situation in import markets). In other situations, a change in climate can reduce the consumption of market goods and the prices of these goods. This could happen in the case where much hotter weather makes beach recreation uncomfortable; tourists go elsewhere; and local accommodation prices fall.

What both of these cases have in common is that when production of a market good or service falls, holding everything else constant, so do the profits of firms producing these goods and services and so does the economic welfare of consumers. When the prices of goods and services increase, this can help producers of market goods and services recover some of their lost revenues due to reduced consumption, but it will always reduce the welfare of consumers. The reduction in the economic welfare of consumers and producers of market goods due to the impacts of climate change, without taking into account additional measures to adapt to these impacts, is called "*Climate Change Damages*" (Callaway 2004a). Economists have a variety of techniques for exploiting information about these climate-induced changes in market prices, production and consumption levels to estimate climate change damages for specific sectors. The flavor of this approach is shown diagrammatically in Figure 2.1, using the example of a commercial food crop.

The same principles can be applied to valuing the benefits and costs of avoiding these damages through adaptation (Callaway 2004a, 2004b, 2008, 2009), but the diagrams to show this are quite complex. The notion is that options can be undertaken to eliminate some of these economic damages. They make the area A smaller. That is: they reduce damages (at some cost), and the net reduction in climate change damages (the damages avoided by adaptation) are the "*Net Benefits of Adaptation*". The part of the area A that remains after adaptation has taken place is called the *"Imposed Cost of Climate Change"*. These are the climate change damages that can't be avoided, either because it costs too much to do so, or else is physically impossible.

There are really two types of impacts of climate change:

- Welfare impacts, and
- Impacts on indicators of economic activity.

Those impacts that are depicted in Figure 2.1 are called welfare impacts, because they are based on measures of changes in the welfare of economic agents – producers, consumers, and investors – due to market effects. These net changes in welfare measures the enjoyment that consumers lose or gain when the price of a good and/or the amount they consume changes. They measure the changes in net returns to producers: the revenue they receive from selling goods, less the cost of producing it. Finally, for investors these net welfare changes measure changes in the net returns to investors over time, less their investment costs. The measurement of welfare impacts on all these economic groups is based on a well-developed body of economic theory that tells economists not only how to measure them, but also how to aggregate, disaggregate (and mis-aggregate) them[7].

7 A good text book introduction is Just et al. 1982. *Applied Welfare Economics.* Prentice-Hall.

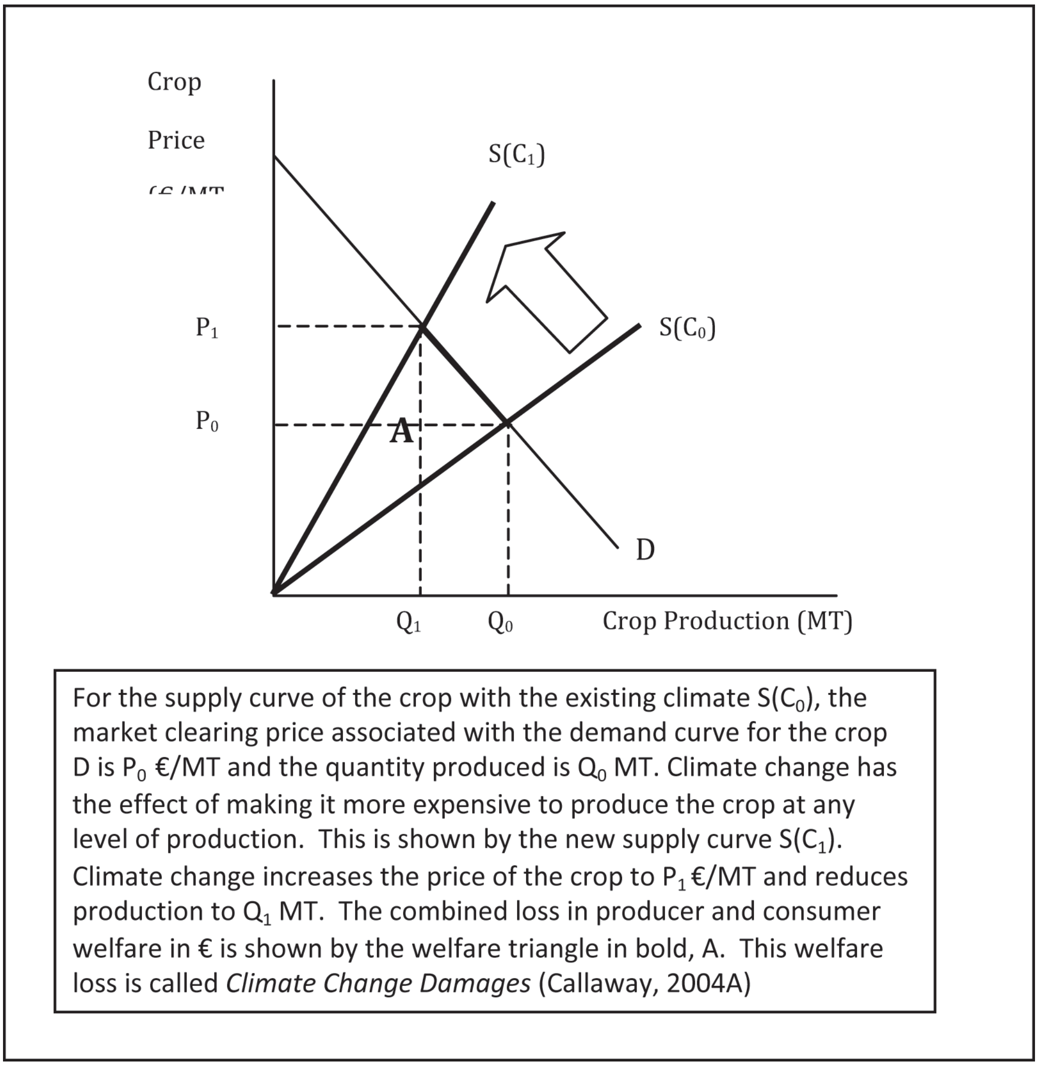


Figure 2.1 Graphic Illustration and Text Showing How Economists Measure Climate Change Damages in Welfare Terms

This study focuses on models and methods for measuring these welfare effects, specifically on approximating the climate change damages due to some impacts of climate change, related to some economic activities (and human health), in some places and/or parts of an economic sector. However, the preliminary quantitative estimates of climate change damages all fall short of being true welfare measures. This is because the models, methods and/or the data to make these calculations have either not been developed in or for Montenegro or were not readily available in published or other, easy-to-access sources.

Impacts on indicators of economic activity are important – perhaps more important than welfare impacts in the eyes of public policy makers and elected officials. These impacts are related to changes in economy activity as measured by gross domestic product, consumer expenditures (consumption), investment and government spending, etc. Labor force participation, employment and unemployment are included in these measures used in national accounting systems. Typically, these impacts are measured in the macro-economy at the national level. Until thirty years ago, roughly, Input-Output (IO) tables were the primary means of estimating these impacts (Miller et al. 1985). But these have given way to computable general equilibrium (CGE) models, which contain a more realistic representation of markets and their linkages (Kehoe and Kehoe 1994). In principle, both models can be used to simulate the transmission of the impacts of climate change on markets (as shown in Figure 2.1) through the inter-industry structure of the economy to other markets in other sectors.

An effort was made to find either an IO or CGE model for Montenegro that could be used to project the impacts of reduced tourism on national gross domestic product and unemployment, but after some initial hope, such a model could not be found in the private or the public sectors. It should be noted, however, that the approximation of climate change damages for the tourism sector is based on changes in spending by tourists, which is not a measure of net welfare, per se. Reduced tourism expenditures represents a savings to tourists (but they may loose the enjoyment they derive from their vacation and the goods and services they purchase) and an economic cost to local merchants. Economic impacts that are measured by changes in indicators of economic activity have this same property: they do not represent welfare changes and adding them up in different sectors and over time often results in double counting of income and or expenditure flows (Just et al. 1982)[8].

2.3. An Introduction to Integrated Environmental-Economic Assessment Approaches

Figure 2.2 is a graphic illustration of all the systems and linkages that can be (and often are) included in an integrated environmental-economic assessment. It's hard to know where to begin, since it's a matter of everything depending on everything else. However, as good a place as any is in the box labeled "National, Regional and Global Economies". This part of the system actually needs several boxes to show the product and expenditure flows between sectors and nations. These flows of goods and money act as "conveyor belts" for economic impacts between sectors and within and between national economies.

The arrow labeled "Emissions" shows that these economies collectively produce greenhouse gas emissions that are transported into the global climate system where they mix and their net forcing effect on climate is determined by the mix of gases, the rates at which they oxidize, and how large their forcing effect is. These forcing effects are then transmitted to local climate systems, where changes in local climates interact continually with the global concentration of greenhouse gas to influence the local environment (both natural and man-made and, directly and indirectly human health (not shown). These local impacts have the potential to shift both the supply and demand for market goods and services in (mainly, but not exclusively) natural resource sectors, such as agriculture, forestry, fisheries, tourism and recreation and water resources (which overlaps and cuts across many different sectors). These impacts are then transmitted from the natural environment to natural resource markets and sectors by changes in the flows of environmental services, some of which are priced in markets and some of which are not. Adjustments to climate change in these sectors occur through adaptive management (and by adaptive investments) that feed back into the local environment and change the flows of environmental services back into natural resources sectors, completing the control and feedback process of adaptation to climate change. Finally, the impacts of climate change, both before and after the adaptive adjustments have taken place, are transferred to the local, national and global economies through the conveyor belt(s) of inter-industry and inter-country commodity, services and money flows. This completes the cycle.

8 As the authors show, the full welfare impact on the entire economy of a shock to the environment can be measured in a single sector (given the right information), because many of the inter-industry impacts amount to welfare transfers between sectors that cancel out, because a supplying industry's benefit is a buying industry's cost.

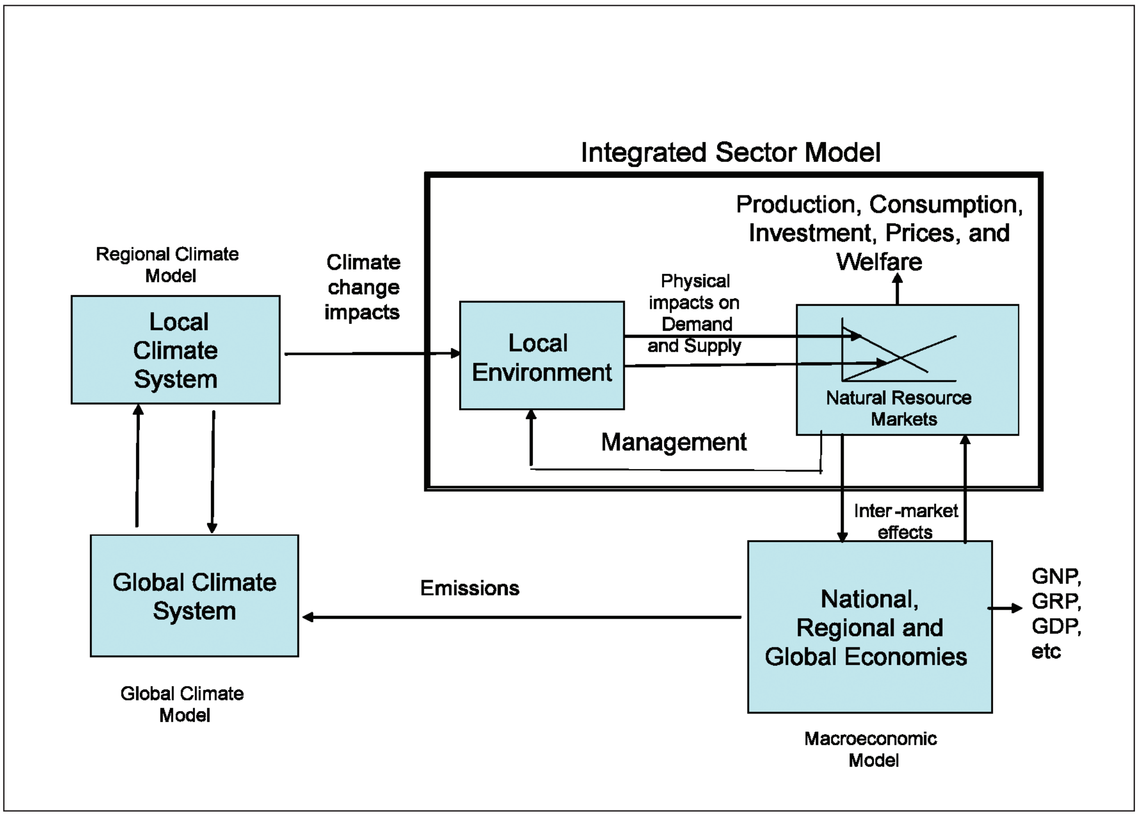


Figure 2.2 Graphic Illustration of the Systems and Linkages, Globally and Locally that Influence the Impacts of Climate Change and Adaptive Adjustments to these Impacts

Each of these systems or, in some cases groups of systems, are also represented by different types of models that can be used assess the physical and economic impacts that occur in each system. In fact, one type of model, known as Integrated Assessment Models (IAMs), capture all of the systems and inter-linkages shown in Figure 2.2. IAMs are widely used to assess the relationships between emissions policies, greenhouse gas emissions, climate change, climate change impacts and adaptation at the global and regional level[9]. However, the level of physical and economic detail in IAMs at the national and local level is often not adequate for assessing and valuing climate change impacts and the benefits and costs of adaptation at appropriate geographic or market scales, although there is much debate about where to draw the lines.

A number of the so called economic sector models that are presented in this study in chapters 3, 4 an 5 have been used in integrated environmental-economic assessments of climate change at the local and national levels to estimate the effects of climate change on commodity markets, to value climate change damages in welfare terms and to estimate the benefits and costs of adapting to climate change. Examples are two studies by Callaway et al. (2008 and 2009) in the Berg River Basin in the Western Cape of South Africa. For these studies, global climate models were used to generate information about climate change over large areas in Africa. This climate information was then downscaled to the basin level using a regional statistical climate model. A rainfall runoff model was used to translate distributed changes in precipitation and temperature around the basin into changes in runoff, reservoir evaporation and plant water demands in irrigated agriculture for a number of different climate scenarios. A spatially disaggregated hydro-economic model developed by Callaway (2008) for the region was then used to simulate how these changes would

9 See reviews by Wyant (1996), Kelly and Kolstad (1999) and Parson and Fisher-Vanden (1997) for a good overview of these models and their uses.

influence long-term investment in new dams (the Berg River Dam) and the operation of the system on a monthly basis. Climate change damages were estimated for the basin without additional investments in reservoir storage capacity and the benefits and costs of the Berg River Dam to reduce these damages were also estimated, using a range of assumptions about the future growth in water demand by Cape Town and irrigated agriculture in the Berg River Basin. A key finding of this study was that changing the way in which water was allocated, rather than building a new dam, produced the largest net benefits of adaptation and was the most immune to climate risk. The finding was important because it highlighted the importance of "no regrets" adaptation options as being both more economically efficient than climate-sensitive measure and "safer" in terms of avoiding the adverse consequences of building too much or too little additional storage capacity in the face of uncertainty about future changes in climate.

The only type of model, shown in Figure 2.2, which the Berg River study did not include was a macro-model of the larger regional and national economy. This is the richest agricultural region in South Africa. Such a model could have been useful to project the effects of climate change and adaptation to climate change in the basin on local and national employment and on local and national income due to the export of grapes, wine and deciduous fruits, such as peaches, nectarines and plums. Adding such an analysis could also have helped to estimate the climate change damages in the region, if the demand functions for food in the model could have reflected up-market economic activity both in domestic and export markets. However, tracking the monetary exchanges through these markets from food producers to processors to food marketers and exporters and then to domestic grocery store transactions and export food demand would not have added anything to the welfare calculations because all these transactions cancel out. A follow-up study for a larger area in the Western Cape is underway and a macroeconomic model will be utilized to assess the impacts of climate change on various indicators of regional and national economic activity.

2.4. Making Preliminary Estimates of the Economic Impacts of Climate Change: What can we Learn?

One of the objectives of this study identified in Chapter 1 is to try to make preliminary estimates of climate change damages in the agriculture and forests, tourism and recreation, water resources and human health in Montenegro. The estimates are preliminary because in every case the data and models, as well as the specific educational training and experience to develop and apply integrated environmental-economic models to estimate these impacts is not well developed, if developed at all. At the same time, there does not appear to be any IO- or CGE-based model for Montenegro to estimate the economic impacts of climate change on indicators of national economic activity. Without these two types of models and related data bases, comprehensive and reliable estimates of either kind of economic impact is just not possible at this time.

However, that does not mean that nothing can be done. In countries, like Montenegro, whose post-WWII experience has been dominated by political changes and economic upheavals, natural resource and social planners and managers in both the public and private sectors have made important decisions with the information and models at their disposal. To say that no estimates of the economic impacts of climate change can be made without detailed data and highly sophisticated, state-of –the-art geo-physical, biological or economic models is not correct. Such models may be able to generate more information that is more reliable and of greater help to public sector policy and private sector decisions. But preliminary estimates, however rough, still have their place in decision-making in both the private and public sectors until (or if) better information is needed.

Making these kinds of preliminary estimates can accomplish three different things. First, preliminary estimates can reveal the general scale of impacts that might be expected. For example, in Chapter 4, the loss in gross revenues from sales of maize is computed for Montenegro, using data on the effects of climate change on production from Croatia. Montenegrins know that the production of small grains and maize is low and concentrated in small, fragmented farms in the northern part of the country. Any climate change impacts that occur to reduce production will not have large monetary impact on the nation as a whole. However, the average annual yield losses that have been simulated for Croatia due to climate change are in the range of 3-8% for the year 2050 and from 8-15% for the year 2100 (Vucetic 2006). If these estimates turn out to be fairly accurate, the impacts on individual farmers, already hard- pressed for cash could become very painful, if they have to buy maize in the market to feed their livestock, or if they have to reduce their livestock numbers to cope with climate change. Taking into account these potential impacts – a 3 to 15 % percent reduction in livestock populations is something to think about, since it will impact consumption of meat products, nationally. Therefore, one might conclude: maybe Montenegro ought to try to develop the capacity to better estimate these economic impacts through the use of crop yield models and an agricultural sector model.

Second, making these kinds of preliminary estimates of climate change damages (or impacts on indicators of economic activity) can help to locate "hot spots" and "hot sectors" where damages may be especially severe and could spill over to disrupt national economic development. Based on this paper, this appears to be the case for irrigated agriculture (Chapter 4), the tourism and recreation sector (Chapter 5) and potentially for hydropower production (Chapter 6), as well. The last two of these sectors have been targeted for aggressive development by the government and private sector of Montenegro, while irrigated area is on the rise and is expected to double or triple in the next 50 years. The results of this paper, as partial as the analyses are, do tend to indicate that climate change in the future (if not already) could impose limits on this growth. Better data and models – physical impact models, sector models and macroeconomic models – are required in all of these cases to confirm this.

Finally, developing preliminary estimates of the economic impacts of climate change can tell us what data and models are missing and what data and models won't work. This is one of those cases were "failure" can be instructive. For example, in the case of the forest sector, the methodology that was planned – to estimate the effects of changes in tree growth rates on, first, the rotation age/size and sequencing of diameter classes on even- and uneven-aged managed forest stands and, second, the net present value from these stands (as reflected in timberland prices). However, this approach failed for a number of specific reasons, namely: systematic information on tree growth increments is not available in the country and transferring data from Croatia did not work, and the age, diameter and species structure of stands in Montenegro, as needed, was not available in published form, nor was information about timber prices and management costs. The latter problems are typical in these kinds of studies. These data do exist, but they are just hard to find. However, the lack of tree growth models and data to calibrate them to stands is a more serious problem. The data problem is being addressed currently by a large forest inventory project in the country. The lack of stand models to simulate tree growth, management and the evolution of the stand timber inventory volumes and structure under different types of management is a more important shortcoming that needs to be addressed to improve the reliability of estimates of the economic impacts of climate change.

From the perspective of all three of these types of results, preliminary estimates of the economic impacts of climate changer are worth making.

2.5. Analytical and Institutional Capacity to Estimate the Economic Impacts of Climate Change, a "No Regrets" Approach

Another of the objectives of this study is to assess the analytical and institutional capacity to estimate the economic impacts of climate change. What is meant by analytical and institutional capacity? What are the differences between the two? What is the best way to develop these types of capacities in a country where, arguably, considerations of climate change may be secondary to considerations of economic development?

First of all analytical capacity is the capacity to develop and use various types of data bases and models discussed in this report to estimate the economic impacts of climate change. Institutional capacity refers to the ability of natural resource and social and health planners and managers in both the public and private sectors to use the information generated by the new data and models to make better investments and policies that will reduce climate change damages. The two do not necessarily go hand and in hand and analytical capacity is probably easier to develop than institutional capacity which has to filter through public and private sector institutions before it gets adopted.

A bigger issue is why a country that is developing (or wants to develop) quickly should be spending time and resources to develop analytical and institutional capacity to evaluate the economic impacts of climate change and the net benefits of adapting to it when, arguably, there are more pressing social and economic development issues. This is where the concept of "no regrets" enters the picture. A public or private sector policy or plan or law or even project has "no regrets" associated with it, if the benefits associated with its implementation are positive, whether or not climate change occurs, and are also positive if climate change does occur. Take, for example, the alternatives of coping with climate change by building more storage capacity versus changing the way in which water is allocated. Changing the allocation system is a "no regrets" option if it results in more efficient water use and increases the economic value of water in use if climate changes or if climate does not change. In that sense, it is good for economic development and it is good for coping with climate change. Increasing water storage, however, costs a lot of money and it is important to size reservoirs correctly. The "optimal" size of a water supply reservoir can depend a lot on climate change. So, there is always the possibility of experiencing regrets of building a reservoir that is either too big or too small, based on a future projection of climate change. A reservoir that is "too big" is one that can't be filled and some of its storage capacity will not be utilized when the climate changes. A reservoir is too small, if water that could be stored and used later has to be released downstream. In the first case, the "regrets" come in the form of excessive costs, while in the second case, the "regrets" come in the form of lost benefits.

A no regrets approach to capacity building is the same as planning for climate change, as shown in the above example. It involves developing the analytical and institutional capacities to plan, manage, make policies and set standards, etc. in both the private and public sectors that are generally needed to guide the economic development of a country and which are also helpful for coping with climate change. In some circles this is known as a "win-win" situation. Take the case of the water resources sector, once again. There are a variety of development issues in Montenegro related to water resources and planning. The most obvious one that comes to mind are plans to greatly increase the generation of power by hydroelectric plants. Developing hydro-economic models like those described in Chapter 5 would be a great aid to water resource and energy planners, even without the issue of climate change to worry about. However, since climate change will affect both the demand for electricity, as well as the supply of water used to generate electricity, such a model is also valuable for integrating the impacts of climate change into water resources and energy planning.

In the next four chapters, the principles and issues discussed here are applied to the agricultural and forest sectors, the tourism and recreation sector, the water resources sector and human health.

3. CLIMATE CHANGE DAMAGES IN THE AGRICULTURAL AND FOREST SECTORS

3.1. Introduction: Background and Objectives

3.1.1. Background

The domestic Montenegrin agricultural sector is composed largely of small farms, producing for household and local market and national consumption. It is a relatively small sector, which together with the forest sector accounted for about 7.5% of GDP and less than 8 percent of the total labor force in 2008. The distribution of agricultural land use is shown in Figure 3.1.

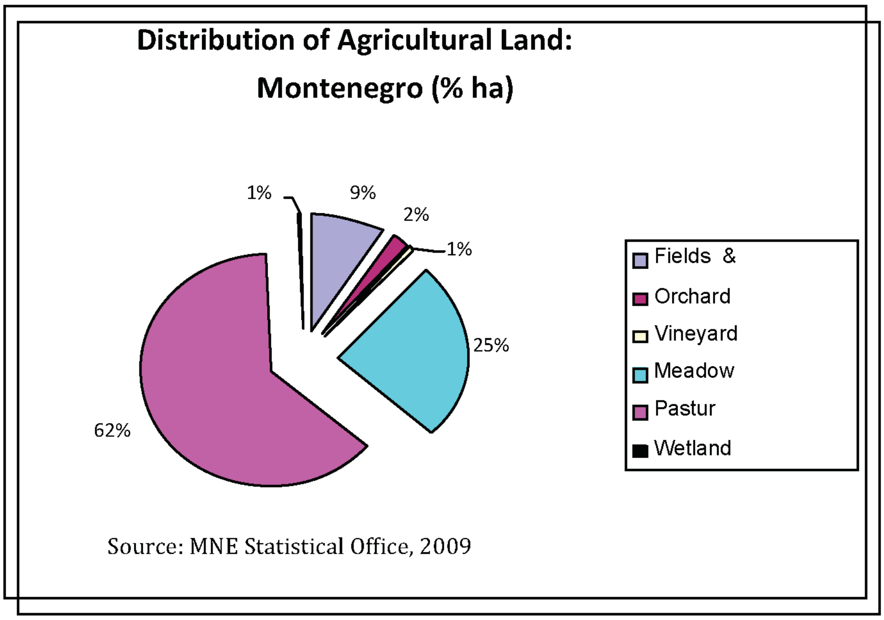


Figure 3.1 Distribution of Agricultural Land Uses in Montenegro

Over 60 percent of the roughly 520,000 ha of agricultural land in the country is used for grazing of relatively small holdings of livestock and this figure rises to over 85 percent if one takes into account meadows where grazing occurs. This is not surprising since livestock production (mainly cattle, sheep and goats) accounts for a significant part of the income generated by this sector. The livestock sub-sector is, however, mainly composed of small farms, fragmented geographically. Increasing livestock production and improved marketing is a major development goal of the government. If this is successful, it could also increase the production of cereal crops to feed livestock. The future of these two sub-sectors is definitely related.

The next largest category of land use is fields and garden, which utilizes about 9 percent of the agricultural land with vegetable gardens and field crops, including fodder for domestic livestock. Figure 3.2 shows that about 40 percent of this category (arable land) is devoted to fodder crops, 18 percent consists of vegetable gardens, and only 11 percent is devoted to growing cereals, such as wheat, barely, oats and maize. Finally, orchards and vineyards, located largely in the Southern portion of the country running from Podgorica to the sea, constitute about 3 percent of the total agricultural land. This area is partially irrigated and target for expansion over the coming decades, primarily for export. It includes table and wine grape production, and other fruit crops.

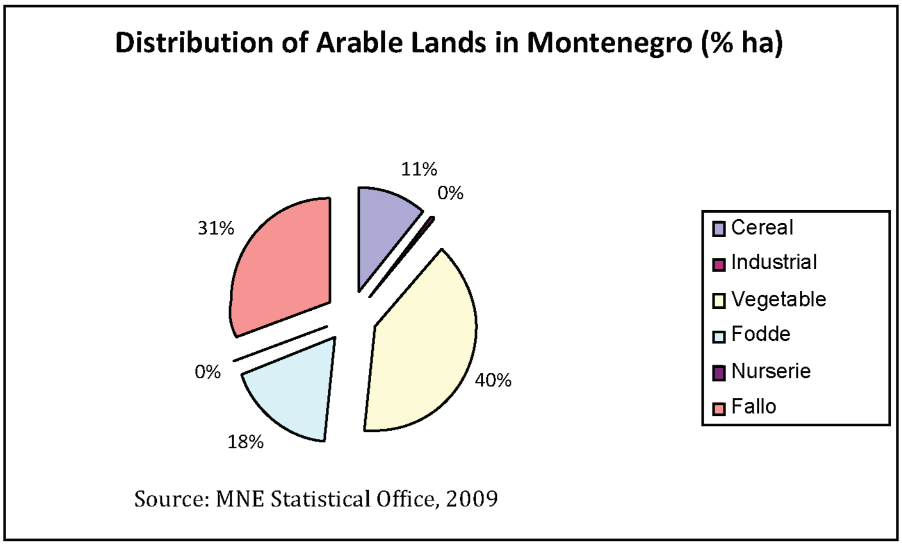


Figure 3.2 Distribution of Land Uses of Arable Lands in Montenegro

About 740,000 ha of land in Montenegro are forests and forest lands (620,000 ha are forested, remaining 120,000 ha falls in the category of forest land). State owned forests and forest land make up 67% of the total surface, while remaining 33% are privately owned. High forests (sections of commercial forests that are economically most valuable) devoted to intensive management for commercial purposes are spread over around 250,000 ha, mainly in northern and north-eastern parts of the country. Figure 3.3 shows the distribution of this timberland according to species types and whether it is composed of a single or mixed species.

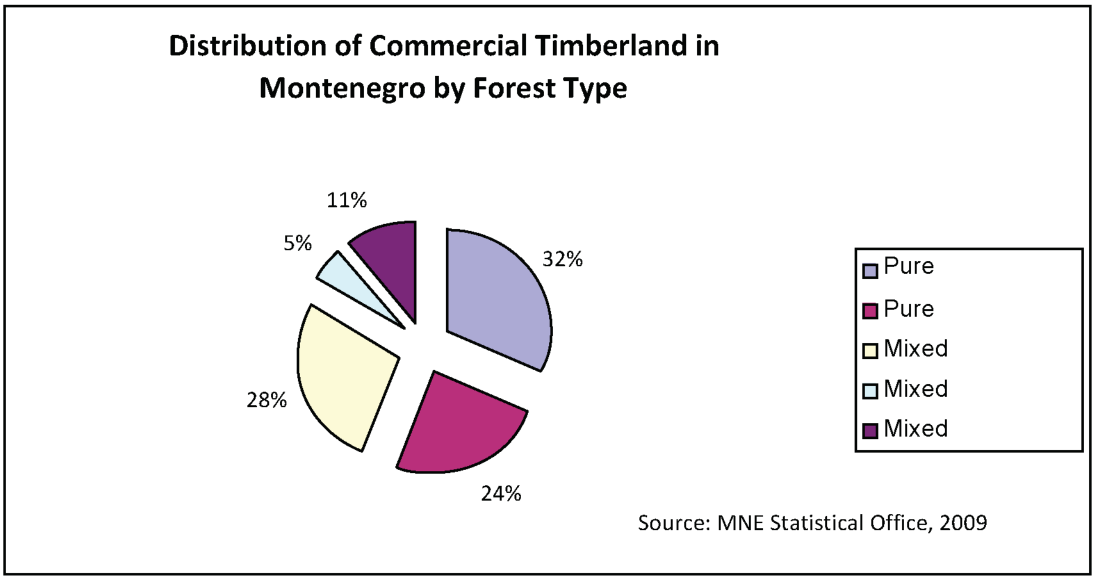


Figure 3.3 Distribution of Commercial Timber Land Uses in Montenegro

About 56 percent of the land is managed with a single species type of forest (in either conifers or deciduous trees), while the remainder consists of various mixed species. Current forest inventory data is limited, but in the process of being developed through a comprehensive new program to survey and estimate the forest inventory. However, the main deciduous forest types are beech and oak; the major coniferous forest types are spruce-fir, while the mixed stands are composed of beech, oak and other species, along with fir and spruce. Ownership of private forest land and the logging industry in general is composed of relatively small establishments. The stand structure of most of these forests is primarily uneven-aged. That means that trees are harvested in small areas when they reach a specific size (or age). This type of management is consistent with the small-scale character of the forest industry in Montenegro, and while it is not as economically efficient as even-age management, it is environmentally sounder in that it conserves soil, reduces flooding and provides better wildlife habitats.

Even though the Montenegrin agricultural and forest sectors are relatively small, that does not mean that the impacts of climate change are unimportant to the economy of the nation as a whole. This is particularly true in the agricultural sector. From a food security standpoint, a great deal of domestic production is consumed domestically. Reductions in crop yields and the productivity of live-stock due to climate change, as discussed later in this chapter, can probably be offset by expanding crop area, but the cost of establishing new land and the reduced productivity of crops and livestock will make newly established crop land more expensive to farm. As a result, much of the lost production could well be replaced by imported agricultural commodities, causing dislocation of the rural population at a faster rate than is desirable as the economy develops. However, the impacts of substantial increases in some sectors, such as livestock and fruit production on supplying and processing sector is hard to forecast without sector and sub-sector models. For example, substantially increasing livestock production will increase the demand for a larger "finishing" industry and this, in turn, could stimulate either domestic feed crop production or increase feed imports. Without sector models to evaluate the profitability of these alternatives and how well they compete with one-another at the farm level, it is very hard to predict what will happen.

The economic impacts of climate change on the forestry sector are less straightforward for several reasons. First of all, forests are subject to more sources of both manageable and unmanageable stress and disturbances (from pests, diseases and fire) than the crops and the effects of any of these stresses at a given point in time can have long-term impacts. For these reasons, it has been difficult to establish, empirically, the partial and combined effects of all these sources of stress on tree growth and development at local scales, except by using very sophisticated models that have not been calibrated for Montenegro .The use of sophisticated simulation models of forest growth and geography (Schimel et al. 2000; IPCC 2007) has established that sustained increases in average daily temperatures and reductions in average daily precipitation will, by the end of the century, have a negative effect on tree growth rates; however, shifts in the geographic distribution of species are harder to depict because they also depend on a host of other environmental and management-related factors that are not easy to predict. Reductions in tree growth rates will have economic repercussions. At the very least, trees will not grow as fast and this means it will take a longer time for trees to reach their cutting ages, and that harvest volumes will fall, reducing revenues and negatively impacting the industry.

3.1.2. Objectives

This chapter has five main objectives. First, in Section 3.2 it summarizes how the agricultural and forest sectors in Montenegro may be affected by climate change. Second, in Section 3.3, it describes the methods available for estimating the economic value of future climate change damages in these sectors. Third, in Section 3.4, it evaluates the current capacity that exists in Montenegro to estimate the economic value of climate change damages using state-of-the art models and methods. Fourth, in Section 3.5 it provides very preliminary estimates of the economic value of some of the climate change damages that can be calculated, now, given the information available to this study. Finally in Section 3.6, it suggests how the analytical capacity to improve on these estimates and the institutional capacity to use this information to make public and private sector policy can be further developed.

3.2. Potential Impacts of Climate Change on the Agricultural and Forest Sectors

3.2.1. Agriculture

From the standpoint of the agricultural sector, the most important influences of climate change will be the impacts on the Net Primary Productivity (NPP) of crops and livestock through changes in the average values and temporal and spatial distributions of temperature, precipitation and the availability of irrigation water. Increases in the frequency and/or intensity of storms can result in increased crop damages from high winds, strong rain and hail, increased crop losses due to flooding of riparian lands, and water logging of cropland due to higher water tables and poorly drained soils. Any tendency toward increases in the frequency and intensity of draughts will also have adverse effects on agricultural and livestock production that can last for longer periods of three-five years.

Currently, about the only available, comprehensive source of information about climate change and its potential impacts on agriculture is the First National Communication by Montenegro to the UNFCCC (MSPEP, 2010). This report shows generally increased temperatures could be expected, occurring throughout the year and in all regions, with the largest increases occurring during the summer in the Southern-third of the country between Podgorica and the coast. Projected changes in precipitation are more uneven. However, the Southern third of the country is generally expected to experience reduced precipitation in December through August. This is not good news for Montenegro since this area accounts for almost all of the irrigated fruit production in the country, representing the highest commercial production value in the agricultural sector. There is sufficient information in Montenegro's First National Communication to give a preliminary indication of the magnitude of the economic impacts that fruit producers can expect due to climate change in the future.

Virtually all of the physical impacts in the agricultural sector of atmospheric build-up of greenhouse gases involve changes in the productivity of agricultural land and livestock (IPCC 1990, 1995, 2001 and 2007)[10]. Table 3.1 highlights in a simple way the major impacts of CO_2 build-up and climate change on the agricultural sector that might occur in Montenegro. This assessment is based on the IPCC's Third and Fourth Assessment Reports (IPCC 2001 and 2007) and Montenegro's First National Communication to the UNFCCC (MSPEP, 2010).

10 This refers to the findings in the four major IPCC assessment reports from 1990, 1995, 2001 and 2007. http://www.ipcc-wg2.gov/publications/Reports/#AR

Source	Effect
Increases in CO_2 concentrations	Increase in long term yields of some crops More rapid growth of some particularly noxious weeds Increased competition from these weeds for available resources
Increases in temperature	Increases in crop yields (and land productivity), up to a point followed by decreases Increases in productivity of livestock, up to a point followed by decreases Reduced irrigation water supply Increased irrigation water demand Complex effects on weeds, insects Adverse effects on animal health due to heat stress
Decreases in precipitation	Decreases in crop yields (and land productivity) Decreased irrigation water supply Increased irrigation water demand Complex effects on weeds, insects and animal health
Increases in magnitude and frequency of extreme events	Increase in crop damages due to drought, flooding, hale and wind storms Increased crop losses due to flooding Greater livestock loss due to droughts and floods
Interactions: higher CO_2 and higher temperature (1-3^{0}C)	Northern part: small positive effects on land productivity and yields Southern part: reductions in land productivity and yields Near future – far future: increasing negative effects on land productivity and yields

Table 3.1 Summary of Potential Physical Impacts of Climate Change on the Agricultural Sector in Montenegro

Many studies have shown that increases in ambient CO_2 concentrations can result in long term increases in crop yields. But the effect is not the same for all crops. Depending on how a plant converts CO_2 into biomass, high concentrations of CO_2 in the atmosphere (550 ppm) have the effects of increasing average annual crop yields from 0-20 percent, or more (Ainsworth et al. 2004, 2005; Gifford 2004; Long et al. 2004). That may sound like a good thing; however, higher concentrations of CO_2 can also cause some particularly noxious weeds to grow more vigorously and out-compete agricultural crop species for water, minerals and sunlight. Moreover, a number of recent studies have shown that changes in temperature and precipitation due to CO_2 build-up can modify and frequently limit the direct effects of elevated CO_2 on crop yields (IPCC 2007).

The individual effects of changes in temperature and precipitation (due to climate variability or climate change) on crop yields vary, as each parameter changes. As temperature increases (along with solar radiation) during the growing season plant productivity increases and then begins to decrease until the plant dries up to the point where it wilts and dies. Increases in precipitation generally are good for plant growth during the growing season, while reductions in precipitation reduce crop yields.

However, at some point increases in precipitation do reduce crop yields due to flooding of the roots. By the same token, temperature and precipitation peaks are generally bad for plant growth due to heat stress, root zone flooding or mechanical damage that is only partially reversible over the crop season by changes in management.

We also know that increases in temperature and CO_2 have a potential to interact with each other in different ways over space and time. According to the latest IPCC report by Working Group II (2007), the effects of global warming on crops vary systematically over time and space. (This same general conclusion applies to forests, although recent increases in observed yields, both due to warming and probably higher CO_2 concentrations are better documented and more wide-spread). At mid-high latitudes, the interaction is positive: higher temperatures and increases in CO_2 reinforce one another and produce even higher crop yields. This interaction increases as one moves pole-ward. At low latitudes, where it is already quite hot and precipitation may already be limiting, the interaction effect on crop yields is negative: the negative effects of increasing temperatures counteract the positive effects of higher CO_2 concentrations and yields fall. This spatial interaction has a temporal analogue in mid-high latitudes. At first (say until about mid-century), increases in both average annual growing season temperature and CO_2 concentrations are projected to reinforce each other and result in increased crop yields. However, by the turn of this century, mid-high latitude temperatures are projected to be so high that the negative effect of high temperatures on crop yields will dominate the fertilizing effect of CO_2, such that crop yields are projected to decline almost everywhere below the Arctic Circle, not just in tropical regions.

Changes in temperature and precipitation also affect the productivity of livestock to provide food and work. The effects are both direct and indirect. As temperatures increases, animals use less energy to keep themselves warm and have more energy to convert feed into work or the production of milk and food. However, beyond some threshold, the process reverses and further increases in temperature reduce the productivity of animals. At the same time, increases in temperature and reductions in precipitation that reduce the productivity of grazing land and the productivity of livestock will fall as the amount of fodder is reduced and/or animals have to work harder to find fodder.

3.2.2. Forests

In general, the impacts of climate change on the forest sector and valuation of the climate change damages in this sector have received much less attention than in the agricultural sector. This is probably because forest ecosystems are much more complicated (and harder to model) than commercial agricultural ecosystems: These systems are subject to a wider variety of stresses, the sources of which are often more difficult to detect and mitigate than in the agricultural sector. Finally, tree growth and development is a dynamic process that takes place over years and not weeks or months. The direct and indirect impacts of climate change affect not only current developmental processes and growth, but usually have both carry-over and cumulative effects that can last for the life-time of the tree. This makes it more difficult to sort out the effects of climate change from other stresses and requires long-term studies – decades long – to characterize the cumulative impacts of changes in temperature and precipitation.

Table 3.2 summarizes the potential impacts of elevated CO_2 concentrations and climate change on forest growth and development.

The general thrust of the impacts summarized in Table 3.2 suggests that forests will not be as adversely affected by climate change as some other sectors. Indeed, rising atmospheric CO2 concentrations, increased growing season length due to recent warming trends, higher rates of nitrogen deposition (also due to air pollution) and other human factors have resulted in a observed increases in annual forest CO2 storage capacity and NPP over the past few decades (Nabuurs et al., 2002). This has been confirmed by estimates of global net primary production from satellite data. Vegetation indexes indicate an average global increase of around 6 percent for the period1982 to 1999, with large increases in tropical ecosystems (Nemani et al. 2003). These and other recent observations motivated the IPCC to report in its Fifth Assessment Report (IPCC 2007) that "contrary to the findings of the Second Assessment Report (SAR), climate change will increase global timber supply and enhance existing market trends of rising market share in developing countries".

The evidence from satellite data is supported by current information regarding the positive effects of CO_2 on forest NPP. Both the VMAP[11] studies conducted in the mid-late 1990s (VMAP Members 1995) and more recent Free-Air Carbon dioxide Enrichment (FACE) experiments confirm that CO2 fertilization in the atmosphere will enhance tree growth. However, more recent FACE-type experiments suggest that the effects on forest NPP will not be as large as suggested in pervious studies, such as VMAP, perhaps in the average range of 20 percent and not 30 to 40 percent for young stands (Norby et al. 2005). On the other hand, older stands are probably less affected (Korner et al. 2005) since older trees grow more slowly and are less efficient in their use of CO_2 to create biomass through photo-synthesis.

The effects of increases in temperature and decreases in precipitation on forests are not so clear cut as in agriculture. This is partly because it matters where a forest is located, geographically and climatically, in terms of its upper and lower boundaries, where temperature and precipitation are limiting to growth. If a forest composed of a specific species is at the lower end of its temperature range, but at the high end of its precipitation range, then an increase in temperature and decrease in precipitation would have the effect of creating more optimal conditions for tree growth. But the effects would be reversed if the same forest was located at the high end of its temperature range and the low end of its precipitation range. In that case, the species could be expected to migrate naturally (which is a slow process) or through management, a form of adaptation.

11 This was an early comparison study of vegetation models used to simulate climate change.

Source	Effect
Increases in CO_2 concentrations	Increase in long-term net primary productivity (NPP) of most trees Differential species impacts that could effect the competition and succession, particularly in mixed forests. Unknown interactions with other stressors, but should make trees less vulnerable
Increases in temperature	NPP response depends on where forest species are in relation to their temperature ranges. In the short-run, warming can lengthen growing seasons. Where temperatures are limiting, the impact on NPP will be negative. Species can adjust by migration, naturally or managed, but at some point, higher temperatures become limiting to growth over large areas. Differential species impacts could effect the competition and succession, particularly in mixed forests Complex effects on other stressors, such as insects and diseases Can interact to limit or enhance CO_2 fertilization Increases in vulnerability to forest fires
Decreases in precipitation	NPP response is also dependant on where forest species are in relation to their precipitation ranges. (Same general types of effects as above)
Increases in magnitude and frequency of extreme events	Long-term increases in droughts and floods will probably have a negative impact on NPP However, forests can adjust their ranges to a certain extent Increases in forests fires will have short- and long term negative consequences on NPP
Interactions: higher CO_2 and higher temperature (1-3^{0}C)	Generally positive effects on NPP, probably lasting longer than for crops Eventually, negative effects on tree growth, but the time frame is uncertain. Existing ranges and geographic distribution of species will be altered naturally and/or by human management.

Table 3.2 Summary of Potential Physical Impacts of Climate Change on Forests in Montenegro

Increases in temperature and decreases in precipitation also have the potential to alter the disturbance regime of forests by extending the range of some damaging insects. This has been observed during the last 20 years for bark beetles in the USA
(Williams and Liebhold 1996 and 2002) and pine processionary moth in Europe (Battisti et al. 2005). The impacts of increased temperatures on forest fires disturbance is a long-term subject of controversy. One group of forest fire studies suggests that climate change will increase the incidence and magnitude of forest fires. For example Gillett et al. (2004) found that about half of the observed increase in burnt area in Canada during the last 40 years, is in agreement with simulated warming from a general circulation model (GCM). Other studies emphasize the importance of more knowledgeable forest management, economic development and forest fire fighting as the largest factors influencing the incidence and size of, as well as damage done by forest fires globally.

A number of studies have estimated the economic impacts of climate change, in the US (Sohngen and Mendelsohn 1998, 1999; Alig et al. 2002), Europe (Solberg et al. 2003; Schroeter 2004; Nabuurs et al. 2002) and globally (Sohngen and Sedjo 1999; Perez-Garcia et al. 2002; Lee and Lyon 2004). These studies used national, regional or global economic sector models of wood products markets in which the impacts of climate change were introduced as changes in NPP of different species, or forest types or biomes. These studies generally predicted moderate increases or slight decreases in the economic well-being of consumers and producers in these markets, along with moderate decreases or slight increases in timber prices. These types of results are not out of line with reality. As Shugart et al. (2003) noted in their global study, global and many national timber and wood product markets are not very vulnerable to climate change, due to the size of existing forest inventory (stock of timber), the existence of flexible import and export markets for both stumpage and wood products, and technological change which has contributed greatly to the productivity of existing forests and reduced wood use. In countries, such as Montenegro, where the existing timber supply is not utilized very efficiently, improved silvacultural and management practices can compensate for some of the losses in NPP that may occur due to climate change, given the proper economic incentives.

3.3. Approaches and Data Needs for Valuing the Physical Impacts of Climate Change in the Agricultural and Forest Sectors

3.3.1. Agriculture

There are at least three approaches that have been used to value the impacts of climate change in agriculture and many other sectors/impact categories, as well:

- ***Agronomic.*** This approach relies on the observed response of crop yields to different soils, climates, and management regimes to simulate changes in average annual crop yields. Independent projections of crop prices and crop areas are used to convert these yield changes into economic values.
- ***Agro-economic.*** This approach combines the agronomic approach to determine the impacts of climate change on crop yields with agricultural market models to determine crop production, prices and economic gains and losses due to climate change. These methods are often "normative" (optimization-based) in that the results are consistent with both agronomically "optimal" and economically efficient management.
- ***Ricardian.*** This approach relies on the observed responses of food consumers, farmers and their suppliers, as reflected in agricultural land prices, to different aspects of climate variability to determine how these groups will respond to climate change. This approach falls under the heading of "revealed preferences" in that sense that the preferences of economic agents can be revealed by their behavior, thus making it possible to attach economic values to market outcomes under various climate variability/climate change scenarios. These methods are "positive" rather than normative. That is: they make it possible to simulate how economic agents actually act (as revealed by their observed choices in the markets for products and/or assets), not how they should act under perfect competition.

Agronomic Models

An agronomic model is based on a model for simulating the effects of changes in climate at various time and spatial scales on crop yields, under different geo-physical conditions and management regimes. Such a model can take the form of a simple, single equation, regression model or a numerical simulation model. The state-of-the-art in agronomic modeling consists of simulation models, like those developed under the names of CERES (Tubiello et al. 2002), EPIC (Stöckle et al. 1992) and WOFOST-DSSAT (van Diepen et al. 2007), all of which support a number of row crops, with more under development. These models are readily available "off the shelf", but must be calibrated to local geo-physical and climatic conditions by trained agronomists, agricultural engineers and agro meteorologists. In most cases, this applied work is supported by crop-specific plot level agronomic research and by larger field studies at the farm research level to look more closely, for example, at disease and pest management issues.

These models simulate the effects of daily weather on the growth and yield of individual row crops. As such, they need daily observations on a number of meteorological variables, as well as information about the physical environment in which the crop is grown related to soils, drainage, water uptake, etc., and "management". These types of models can also be used to simulate a number of different types of management practices related to the type, timing and quantity of inputs (water, fertilizer, harrowing, plowing, etc.) applied. The relevant output of these models is the physical yield of the crop that can be harvested in weight units.
These types of models are generally calibrated from plot data at a few locations and then the calibrated model is used in a representative fashion to simulate yields over a number of other locations with the same geo-physical and climatic characteristics as the plot locations.

An illustration of how such a model can be used to estimate the economic impacts of climate change appears in the recent Human Development for Croatia, *A Climate for Change* (UNDP 2008). This study was based on research by Vucetic (2006) who used the CERES- MAIZE model to estimate the impacts of different IPCC climate scenarios on maize production in Croatia. The simulated reductions in yield ranged from 3-8% for the year 2050 and from 8-15% for the year 2100. The authors of the UNDP study evaluated these reductions using historical data on the area of maize production and the average annual producer price and came up with estimates of economic (revenue) losses on the order of €6-16 million for the year 2050 and €31-43 million for the year 2100, compared to revenues of €199 million for the historical base case.

One of the biggest benefits of these types of models is that they can be used in a wide variety of different applications, not just climate change. In that sense, developing the capacity to use such a model in a country is one of those "no regrets" decisions, previously mentioned. Another important strength of this approach lies in the accuracy of its estimates of yields, compared to older, empirical models. There are several weaknesses. One has already been mentioned. The structure of these models is not amenable to simulating the growth of fruit trees and vine-crops. Another is that they are fairly data-intensive, but this is only a problem in a data-poor environment. Finally, these models can not simulate how farmers and markets will react to climate change. Climate change has the potential to influence the relative profitability of crops and this will, in turn, influence not only how much land farmers allocate to different crops, but also the cost/price at which the commodity can be produced/purchased. An agronomic model can not simulate the effects of climate change in the framework of economic farm-level decision-making or agricultural commodity markets. These models can be used to simulate management actions, such as row spacing, different tillage methods and planting date, but these inputs are not determined by the model. The user must enter this information into the model. The model can then simulate the resulting effects on crop yields.

The data needs of agronomic models are fairly intensive. These models project crop yields for areas that have homogenous geo-physical conditions, climates and managements regimes. These factors can vary widely over space, so for any given country, it is likely that the model will have to be calibrated at a number of different locations in order to get the most accurate results for the effects of climate change on the yield of a crop. All crop yield models require slightly different geophysical and management data sets for calibration. However, the one thing they share in common for calibration and simulation purposes is the need for data sets with daily meteorological observations for the necessary input variables. For simulating climate change there is the additional requirement of transforming the meteorological variables produced by Regional Climate Models (RCMs) to a daily time scale using a weather generator, as was done by Vucetic.

Crop yield models, like the various CERES, EPIC and WOFOST models, have already been developed for a number of short-term (annual) crops. (Models of long-term crops, such as vines and fruits are far more complicated and fewer in number; this represents a large gap in the state-of-the-art for climate modeling purposes). These models project crop yields for areas that have homogenous geo-physical conditions, climates and managements regimes, and in this sense they are generalizable across all these factors. That is: given the appropriate geophysical and climate data bases, they can be run for any location and the results can be generalized to other locations with similar characteristics. That is the good news from an application standpoint. However, since the factors that influence crop yields can vary widely over time and space, the need to calibrate this model at representative locations can be hard in a data-poor environment. Fortunately, these models already have a large amount of human capital invested in them and because a number of centers-of-excellence have grown up around these models, there is no need for a country to think about developing entirely new crop yield models. At the same time, the EU, FAO, WMO and NASA to name a few organizations, have been co-operating with these and other centers-of-excellence to build the necessary data bases to calibrate and run these models on a global scale.

The major tasks that do need to be performed involve:

- Calibrating the models to local geophysical and climate conditions, and
- Using them to simulate yields for a number of representative geophysical regions and climate scenarios.

While crop yield models assume that plant structure and processes for any given crop can be generalized over wide areas, the structure of the agricultural economy is much less general from region to region. Thus, there is no such thing as a one-size-fits-all agricultural sector model. If a region lacks such a model, it must be constructed from the ground up. This is an intensive process, but one which can be readily replicated by trained experts, if the data needs of this task can be met.

Agro-Economic Sector Models

Agro-economic sector models overcome the main limitation of agronomic models by using the projections from agronomic crop yield (and also from livestock) models to drive very sophisticated agricultural sector models, sometimes known as spatial equilibrium models (McCarl and Spreen 1980). Spatial equilibrium models simulate the decision making processes of producers and consumers in many different agricultural commodity markets, accounting for trade and shipments between sub-national and international regions. In that regard, they can be characterized as multi-commodity market models of food supply and demand in many demand and supply regions.

Simulating the effects of climate change on a single crop even over many different locations is far from the end of the story since, once a farmer knows that the climate is changing, he also knows it will affect the relative profitability of many different crops he can grow. He also knows that he will have to sell the crop into a national and/or international market where the effects of climate will influence the crop selection, management and production levels of many other farmers, not to mention the equilibrium market price for each crop and, ultimately, his net income. This knowledge will motivate him to think about what crops he will plant and when and how he will manage them, based on his expected net income and the climate and market-price risks associated with different crop combinations.

Sector models can take these farmer-market interactions into consideration in both a climate variability and climate change context. Like crop yield simulation models, agricultural sector models represent a "no regrets" approach to improving the agricultural modeling expertise of a national government. These types of models are used in developed countries to assist policy makers to explore a variety of policies related to the impact of climate variability on the sector, as well as to support national agricultural development and marketing strategies in the context of modern market economies.

To model how climate change will affect crop mixes, production levels and crop prices at the national level one needs a "price-endogenous" spatial equilibrium (SE) sector model for the agricultural sector. Price-endogenous simply means that crop and food product prices are an output, not an input, of the model. Spatial equilibrium means the model represents differentiated production possibilities over space and transport of products across space to markets. Both features are very important for modeling the impacts of climate change, because changes in climate will be non-uniform over space and, because many producers and consumers in many places will be affected differently by climate change at the same time, market prices will also be affected.

SE models can be further modified to include provisions for simulating the effects of climate change on the livestock sector and on the supply and demand for irrigation water (Adams et al. 2001). Furthermore, these models can simulate normative adaptation to climate change in two ways: 1) Adaptation that involves changes in management at the farm level and 2) Adaptation that occurs normally because of farmer reactions to changes in product prices in the market.

As indicated above, this type of model is structurally a multi-crop, multi-area (world, multi-national entity, or nation) model that captures both the national and export demand for domestically produced crops and the demand for imported food, as well the processes that affect the supply of different crops, over different production areas, to meet domestic and export consumption. Such models are generally process models (non-linear programming models) composed of:

- An objective function that allows the calculation of the welfare of producers and consumers represented in the model, for example: maximization of consumer + producer surplus
- Domestic and excess (exports - imports) demand functions for food goods (crops, oils, seed, feed and livestock)
- Management process activities that represent the various technical options associated with the planting, management, harvesting, further processing and shipment of food goods, including the average annual yields of each crop in each region (derived from crop yield models)
- A transportation flow matrix linking supply and demand regions, and associated market clearing conditions
- Supply functions for important national primary inputs, and
- Restrictions on various cropping mixes, production levels, and prices to reflect actual versus normative behavior and distortions introduced by national level farm programs.

One very important feature of these models is that, while they are well-suited to projecting the physical and economic impacts of climate change, they can also be used in a much broader framework to investigate the economic consequences of a very wide range of environmental impacts on the sector, as well as the economic impacts of external and national agricultural and rural development policies. The fact that these models can be used to determine the effects of different types of national (or multi-national) farm programs and the interaction between these farm programs and climate change is an important feature that many other methods (such as the Ricardian approach, to be discussed shortly) can not reproduce. Another desirable feature of this type of model is that it can depict and capture management behavior of small farmers who are producing food for themselves and local markets and not for export.

An example of an Agro-Economic Model, currently in use inside the EU is the **EU F**orest and **A**gricultural **S**ector **O**ptimization **M**odel (EUFASOM) developed by Schneider et al. (2008). FASOM is actually a land use model. It contains an agro-multi-country, multi-commodity economic model for the agricultural sector and a multi-country, multi-product dynamic forest sector model that are linked by a common land base and economic objective function. This allows the model to simulate how land moves back and forth between the two sectors as a result of environmental and policy impacts. The model was original developed in the US (Adams and McCarl1999) to examine the market impacts of carbon sequestration policies in the United States that involved reforestation and afforestation (Alig et al. 2001). However, it has also been used extensively to assess climate change damages in the two sectors, as well as the benefits and costs of avoiding climate change damages through adaptation. The EU version of the model is currently being used to explore the mitigation potential of the agricultural and forest sectors in the EU; to examine how other EU energy policies, such as bio-fuels policy, will affect this potential; and finally to determine how climate change impacts in both sectors will affect their mitigation potential and mitigation costs.

The current version of EUFASOM models both sectors at the country level. However, the newest accession countries are not yet included in the model. This is also true for the next round of new accession countries, including Serbia, Croatia and, Montenegro, which will join the EU in the next rounds of EU enlargement. One interesting aspect of the Croatian Human Development report, *A Climate for Change*, is that it has led to the preparation of a project proposal that is now being circulated among donor agencies, to develop the capacity to develop and implement a Croatian "module" for the EUFASOM, which can be used to address a variety of pressing farm and rural development policy issues, including climate change, even before the country joins the EU.

Building a price-endogenous spatial equilibrium model for the agricultural sector is a data-intensive task. It requires:

- Annual time series information on national food consumption and prices by food product required to develop national demand functions for each food commodity that is sold to final demand in the model.
- Additional information on exports and imports (prices and quantities) to develop export demand functions and/or excess demand functions,
- National farm surveys, broken down by production region, to build crop management budgets that reflect the management alternatives for producing each crop in a "representative regional farm(s)" context. For a given crop and management-type (for example, intensive commercial management of corn), these budgets include inputs needed per unit area for various operations and their unit costs, average yield per unit area, and other costs. From this information, one can build thousands or tens of thousands different alternatives for managing 10-30 crops plus livestock categories at the national level. Building adaptation to climate change into existing farm budgets often requires

expanding and/or modifying the management alternatives for crops in existing regions to take into account both a "new" climate and special, climate related adaptation management options/activities (input use, cost, and effects on yields).

- A great deal of other detail on area transportation linkages capacities and costs, storage capacities and costs, existing area crop mixes and production levels, and farm program characteristics to name a few of the items. For example, if irrigation possibilities are included then the model builders must find a way to represent the annual supply of water available for irrigation in each production region and then develop irrigated agricultural crop budgets to represent the production possibilities and costs for irrigated management.

Putting the Agronomic and Economic Models Together

To estimate the value of climate change damages using these models involves two steps. To simulate the physical impacts of climate change on yields at the representative locations one must evaluate and run the representative area models for each crop using the necessary region-specific bio-geophysical data sets and the daily climate data for each climate scenario. The second step consists of inserting these yield values into the SE model and running it to simulate agricultural production and consumption for that climate scenario. The process is repeated for each climate scenario, including a reference case. The differences in yield across the two scenarios reflect the impacts of climate change. The value of the climate change damages for any given climate scenario is found by comparing the value of the objective functions for the climate scenario solution with the reference case.

An important feature of these models is the richness of the output information it can provide. In addition to providing information about the regional and national amount and distribution of consumer and producer surplus, these models also produce information about the effects of climate change and elevated CO_2 on, among other things:

- Regional supply and demand prices for food products
- Domestic production and consumption by supply and demand regions
- National exports and imports
- Type of management options used to adapt to climate change
- Input use, and
- Influence of farm programs (if modeled).

As previously mentioned, the fact that this type of model can provide so much information, makes it extremely useful not only in assessing the physical and economic impacts of a very wide range of environmental shocks and formulating policies to minimize environmental damages at the least possible cost, but also in addressing a long list of important rural development, production, marketing and agricultural trade policy issues.

Ricardian Models

A Ricardian model is a special type of model that relies directly on the observed behavior of food producers and consumers to characterize the economic impacts of climate change. Instead of having to develop special models of food supply and demand to simulate how agricultural commodity markets will respond to climate change, Ricardian models are instead based on two assumptions about the relationship between agricultural land values, climate change and climate variability. The first is that variations in agricultural land values reflect variations in, among other things, climate variability over time and space. The second assumption is that the structure of the underlying agro-economic relationships between land values and climate change and between land values and climate variability are identical. The first assumption is testable and, at least in market economies, is valid when other explanatory factors – including farm program distortions – are held constant. The second assumption can only be tested empirically, slowly, over time as the climate changes. However, even if we can't be sure of this, the assumption is plausible and in widespread use by climate scientists when they use statistical downscaling to translate Global Climate Model results to the regional scale and, to some extent, also by crop scientists when they use the results from physiologically based simulation models to estimate empirical crop yield models (Quiroga and Iglesias et al. 2007).

The basic Ricardian model is typified by a land value equation. This equation explains the variation in agricultural land values over a large number of crop regions as a function of seasonal meteorological variables reflecting both the regional climate averages and variability, and the physical and the socio-economic characteristics of the farm regions used to control for other influences on land prices (Mendelsohn et al. 1994).

To directly estimate the value of climate change damages for specific climate scenarios one must first take the results for the meteorological variables used in the Ricardian model (i.e., average annual precipitation and temperature and interactions between them) from Global Climate Model simulations and downscale them to the same weather stations used to construct the variables of the Ricardian models. Once that is done, it is possible to evaluate the climate variables in the Ricardian models with these downscaled values and then calculate the resulting impact on land values, region by region, using the land value equation.

This type of model was developed by Mendelsohn et al. (1994 and 1999) for the US and further refined in a number of studies of the US by Mendelsohn and various colleagues (See, for example, Mendelsohn et al. 2001 and Mendelsohn and Dinar 2003). The approach has been successfully extended to Canada (Mendelsohn and Reinsborough 2007), Africa (Kurukulasuriya et al. 2006 and Seo and Mendelsohn 2008); Sri Lanka (Seo et al. 2005); South America (Seo 2008), and China (Wang et al. 2009). The developing country studies are of particular importance because in some of the cases, the data to build agricultural sector models does not exist and the Ricardian approach represents the only available alternative for estimating the potential economic value of climate change damages in a rigorous fashion.

The data needs of Ricardian models are much less demanding than those for the Agronomic or Agro-Economic models, but are by no means trivial. The first step of Ricardian modeling is to estimate regression coefficients of the model. To do this requires observed regional cross-sectional data from various sources to develop the values for the dependant and independent variables in the regression equation (land prices, climate, and other factors that influence land prices).

The values for the independent variables in the regression model will vary by study and location. As an example, Mendelsohn et al. (1999) used monthly average temperature and precipitation values and the daily and annual variation in these values for January, April, July and October from county-level weather station data in the US. The control variables required county-level data on income per capita, population density, solar radiation, altitude, salinity concentrations in soil water, flooding propensity, wetland area and a number of soil variables. Other studies have used similar types of data from farm surveys, as well.

Once the model parameters are estimated, simulation is accomplished in the same manner as for the other approaches. The values of meteorological variables in each climate change scenario are downscaled into values consistent with the model variables for the climate scenarios. The values of the control variables are set at their appropriate regional values (some of which have to be projected over time). Once this is done, the regression model can be evaluated for each region in the model and these results can be then aggregated up into national totals.

However, unlike the Agronomic and Agro-Economic models, the information provided by this type of Ricardian model is limited to the effects of climate change and increased CO_2 concentrations on welfare.

Model Comparisons

While Agronomic models are heavily used in economic assessments of climate change, they are generally linked to either Spatial Equilibrium models (Adams et al. 2001) or to National macro-economic models (PESETA Final Report, 2010). However, if these types of models are not available, agronomic models still can shed some light on the economic value of climate change damages, using the approach demonstrated by UNDP in Croatia's latest human development report, *A Climate for Change* (UNDP, 2009).

There has been a long and arduous debate between Mendelsohn and other economists about the relative merits of the Ricardian versus the Agro-Economic models. Much of this debate is irrelevant to more practical issues related to developing the capacity to plan and manage a country's natural resources and then extend that capacity to estimating climate change damages. In connection with this more practical agenda, there seem to us to be at least two basic issues (and the trade-offs between them) involved:

- the limitations of the Ricardian approach to do natural resource planning and management unrelated to climate change and
- the limitations of the Agronomic or Agro-Economic approaches when the data and resources needed to develop these models are very scarce.

The Ricardian approach is not very useful if one wants to answer questions about the best way to manage national resources, if the country does not have a rich and varied history and practice of natural resource management that is reflected in observed land values and instrumental variables to reflect these practices and policies. On the other hand, it does supply information related about the damages due to climate and climate variability (for example flooding and other extreme events) in a resource and data poor environment[12]. By contrast, Agro-Economic models can be used in a "no regrets" framework to assess a variety of different agricultural policy options for coping with climate variability, environmental quality and a host of other agricultural development issues. And, of course, once this capacity is developed it can also be used to estimate the value of climate change damages for various climatic scenarios. But doing so requires an extensive amount of data and the modeling expertise to: 1.) calibrate crop simulation models for different crops, 2.) develop a sampling plan for extending the results of plot experiments to many different regions, differentiated by geophysical and climatic conditions 3.) design and develop an agricultural SE model and to 4.) learn to use these tolls intelligently in a policy framework.

12 Among the countries included in the African study by Kurukulasuriya et al. (2006) was Burkina Faso.

In short, the two approaches present very different functional uses and benefit-cost profiles that need to be balanced in choosing where to develop the needed analytical capacity. Not all countries will reach the same conclusions in making this choice.

3.3.2. Forests

As in the case of the agricultural sector, there are at least three approaches that have been used to value the impacts of climate change in forests:

- ***Biometric models*** that can project changes in the NPP of natural and commercial forests due, directly, to changes in ambient CO_2 concentrations and, indirectly due to forest disturbances that may be influenced by climatic factors. These models can account for the impact of management factors on NPP, but can not be used to value forest inventories or harvests. These models are generally used to provide inputs to the next two types of models.
- ***Management models*** that typically simulate either the impacts of different types of forest management on the size and structure of forest stocks in stands or else can be used in an optimization framework to select the management actions (i.e., establishment of the stand, stand thininngs and stand regeneration) that will satisfy specific management objectives, such as maximizing the asset or production value of the stand, or sustaining an even flow of timber harvests over time. These models can be used to value the economic impacts of climate change at the stand level for managed forests.
- ***Sector (market) models*** (combined with biometric models) that can project the physical impacts of both CO_2 fertilization and climate change on the size and structure of national, regional or global commercial forest stocks, the timing and magnitude of harvests, as well as economic impacts, such as changes in timber (stumpage) prices, the flow of net incomes from forest operations, the value of the standing inventory of trees over time. Global models can typically also simulate trade flows of timber and manufactured forest products.

Biometric Models

Forest economics models have long relied on tree growth models to provide information about NPP. Until the advent of environmental problems like acid deposition and climate change, traditional tree growth models were developed to project annual tree growth increments by tree age and/or diameter classes (or basal area). These models were relatively easy to develop using traditional statistical methods to explain the variation in growth increments as a function of the variation in elevation, soils and average or peak temperatures using either historical or experimental observations. These models did a good job of providing information for growth and yield tables used in forest management models and economic timber supply models. However, all this changed when issues related to acid and nitrogen deposition in forests emerged and, later, when climate change required models of a more long term nature and which focused on ecosystem and/or tree physiology processes that could be selectively affected by air pollutants and climate change.

Today, there are basically three different types of models that have been used (and are still in use in various forms) to simulate the impacts of elevated CO_2 concentrations and changes in climate on forest growth and development:

- Gap models
- Biogeochemical models (BGCM) and Biogeography models (BGM), and
- Dynamic Global Vegetation Models (DGVMs)

The earliest type of model used to simulate the consequences of climate change on forest productivity was the so called “Gap” model[13]. These models simulate individual tree growth and changes in stand growth in a small (0.1 of a hectare) opening (gap) in the forest canopy until the stand reaches its “climax” state, on the order of 300 to 400 years and even longer for some slow growing mixed hardwood type forests. The first such models were developed in the 1970s (Botkin, et al. 1972). During the late 1980s to the mid-1990s these models were used to estimate the impacts of climate change on forest growth due to climate change (e.g., Solomon 1986 and Davis and Botkin 1983). Gap models simulate the response of each individual tree in a stand to light availability at different height intervals, as a competitive process. Trees that grow quickly, but are shade intolerant, dominate the initial structure of the forest. The climax species are shade tolerant, but grow slowly. Eventually, they crowd out the less shade tolerant species and then compete with each other for sunlight until a competitive equilibrium is established. Competition for other resources is included to varying degrees in these models. These resources include soil moisture, fertility (often available nitrogen, specifically) and temperature. This makes it possible to use the models to simulate the effects of changes in these resources due to climate or due to disturbances such as fires, hurricanes, floods, and wind storms.

The original models, by current standards, are fairly simple, but have become more complex over time. The growth of an individual is calculated using a species-specific equation to predict the expected diameter increase for each tree under optimal conditions. This increase in diameter is functionally related to the tree’s previous diameter and is modified by environmental response functions that reflect competition for and the availability of resources, including climate resources. In most of the models, the environmental responses are modeled via a constrained potential paradigm; a tree has a maximum potential behavior under optimal conditions
(i.e., maximum diameter increment, survivorship, or establishment rate). This optimum is then reduced according to the environmental context of the plot (e.g., shading, drought, frost, etc), to yield the realized behavior under ambient conditions.

The original gap models were relatively simple models, whose basic strength was the ability to model competition and succession in a stand. The growth equations were largely empirical and the way in which resource limitations were introduced was based on convenience and not tree physiology. However, if there were sufficient calibration data for a long enough period of time the models could be quite accurate in reproducing historically observed tree growth. While the models were used to simulate the impacts of climate change, their limitations in this capacity were pronounced. Only certain forest ecosystems can be modeled in gap framework; long-term calibration data sets are required to track stand growth from establishment to climax; and the ability to accurately simulate multiple stresses was limited by the fact that these models did not characterize important physiological processes. This made it difficult to simulate CO_2 fertilization effects, for example.

The input data for gap models for a specific study is not very detailed. It includes observed information about the relationship between the diameter of trees and their height and other growth related information. Input data is also required for monthly temperatures and the number of days the temperature is above a certain temperature threshold, plus additional soils information is required to calculate evapotranspiration. A much larger issue is the data required to calibrate a gap model to existing conditions. To do so can require measurements of leaf area index under different environmental conditions, light penetration through the forest canopy, plus observed tree growth information. Gap models typically have nearly as many (or more parameters) to calibrate than they have variables. Thus,

13 See the review of gap models by Bugman (2001)

it has been argued that many different parameterizations might fit the same incomplete data set, but have very different consequences when the model is used to simulate conditions that are substantially different than the base case (Bugman 2001).

Eventually these models gave way to Biogeochemistry (BGCM) and Biogeography (BGMs) simulation models. The different functions of these models eventually merged into the more general, Dynamic Global Vegetation Models (DGVMs). BGCMs simulate changes in basic ecosystem processes such as the cycling of carbon, nutrients and water (ecosystem function) that contribute to Net Primary Productivity (NPP) of forest ecosystems. BGMs simulate shifts in the geographic distribution of major plant species and communities (ecosystem structure). DGVMs simulate the effects of climate change and increases in ambient CO_2 on NPP and the geographic distribution of forests and forest ecosystems as they migrate naturally in response to climate change.

All three types of models are process models. That is they rely on "first principles" to characterize the important physiological processes associated with tree growth and development. Biogeochemistry models estimates fluxes and storage of *energy*, *water*, *carbon*, and *nitrogen* for the *vegetation* and *soil* components of terrestrial ecosystems[14]. Many of these models specialize in more detailed treatment of some fluxes and process than others. In vegetation (forest) models the most relevant processes that control fluxes of energy and mass include:

- Sunlight interception by leaves, and penetration to the ground
- Precipitation routing to leaves and soil
- Snow accumulation and melting
- Drainage and runoff of soil water
- Evaporation of water from soil and wet leaves
- Transpiration of soil water
- Photosynthetic fixation of carbon from CO_2 in the air
- Uptake of nitrogen from the soil
- Distribution of carbon and nitrogen to growing plant parts
- Decomposition of fresh plant litter and old soil organic matter
- Plant mortality
- Fire, insect and disease disturbances.

The first generation of BGCMs simulated the carbon and nutrient cycles within ecosystems in a given place, but lacked the ability to determine what kind of vegetation could live at a given location. BGMs, on the other hand, modeled a limited number of physiological processes but in more dynamic way and so were able to simulate how changes in environmental conditions could influence the geographic distribution of these ecosystems (or biomes, as they came to be called). Thus, assessments of the impacts of climate change conducted up until the late 1990s-early 2000s had to rely on one set of

14 The structure of these models is complex. See Bachelet et al. (2001) for a description of the DVGM, MC1, that is accessible by most experts working across the wide range of fields involved in integrated environmental-economic assessment.

BGMs to simulate the geographic redistribution of forest ecosystems to climate change and another set of BGCMs to simulate the effects of climate change on the NPP of these ecosystems. This was a problem for simulating the impacts of climate change on natural forests, but not managed forests. In economic studies of managed forests, the differential impact of climate change on NPP across many different locations determines the physical potential for any given forest type, but economic factors determine where and when this potential will be exploited.

The recent proliferation of DGVMs has allowed better predictions of climate-induced vegetative changes (Peng 2000; Bachelet et al. 2001; Cramer et al. 2001; Brovkin 2002; Moorcroft 2003; Sitch et al. 2003). This is because these models do a better job of simulating the composition of deciduous and evergreen trees, forest biomass, production, and water and nutrient cycling, as well as fire effects. DGVMs are also able to provide global and regional climate models with feedbacks from changing vegetation. However, the models still do not realistically mimic the process of transient migration of forest ecosystems, and do not necessarily simulate changes in forest productivity any better than much simpler models of forest yields. Future development of models that integrate both the NPP and forestry yield approaches (Nabuurs et al., 2002; Peng et al., 2002) could significantly improve the predictions, according to the IPCC Fourth Assessment Report.

Like gap models, BGCMs, BGMs and DGVMs have "relatively" little input data requirements compared to their calibration data requirements. This feature makes the models ideal for use in connection with data generated by satellite imagery. However, these models are physiology-based process models, and they need a great deal of data to calibrate individual sub models to specific locations (both from the standpoint of geophysical conditions and climate). Typically in a climate simulation modeling framework, these models are driven by climatic inputs from global or regional climate models, the accuracy of some of which – for example, precipitation and runoff – is highly questionable at the time and spatial scale at which these models operate. However, these models were never really intended to produce daily results and when the output data on NPP and geographic vegetation distributions are aggregated, they appear credible (Kitel et al. 2004; Batchelet et al. 2008; Gordon et al. 2004).

Finally, it is important to note once again that the standards for judging forest growth models for use in economic assessments of the impacts of climate change on managed forests is much different than for judging their use in ecological assessments. Managed forests "migrate" due to a combination of economic and physical factors. It is important to know how the NPP potential of managed forests will change over time at different locations to simulate migration that is "managed" by humans through tree planting. Changes in the geographic distribution of NPP can only be determined by a biometric model of some kind. The actual migration of these managed forests from one location to another, however, will be determined by economic considerations related to the relative profitability of different species. The range of production potentials by any given forest type at each location is an input to the calculations of the economic models – both management and sector models to be discussed next.

Management Models

Forest management models use the outputs of biometric models (various measures of tree growth rates) to predict how various management strategies will affect timber harvests and the size and structure of timber stocks in a managed forest, the size of harvests, revenues and net revenues from harvest operations and the asset value of timber land, its land price (Gunn 2007). This requires that these models depict not only the size, age, land productivity and age structure of timber stocks, but also these models must be able to simulate how selected management actions affect the size and structure over time. In addition, many forest management models are designed to select the “optimal” type of management regime over a number of rotation periods that maximizes the physical or economic objectives of the land owner in both deterministic and stochastic (probabilistic) frameworks. As such, these models simulate the decision making process of a timberland owner given: 1) expected current and future timber prices, 2) current and expected NPP of different tree species that the land owner plans to grow (from biometric models) and 3) whatever external policy and physical constraints the land owner faces that will influence decision making. They also simulate the consequences of these decisions on the size and structure of the stock of trees on the stand.

Stand management models were originally designed as management tools for commercial forest land owners (Brodie et al. 1979; Davis et al. 2001). However, the emphasis has shifted somewhat in the last 20 to 30 years, as stand management models have been adapted to exploring a wide range of environmental topics, including habitat diversity (Bertomeu and Romero 2002), evaluation of insurance risks due to disturbances (Holecy and Hnewinkel 2004), the general topic of sustainable development (Hasenauer 2005) and many others. Another such topic is the impact of climate change on commercial forest management and timber stocks.

In climate change applications, biometric models are used to determine how changes in ambient CO_2 concentrations and climate affect tree growth for the species that are or can be grown in a given location. Then, these growth estimates are used by stand management models to project the way in which commercial timber land owners would manage existing and new stands of trees, by thinning, harvesting and establishing existing or different species. In one interesting and path breaking study, Lindner (2000), adapted an existing gap model to simulate the effects of different tree planting (establishment) regimes on the gap forest as it was influenced over time (110) years by climate change. Gap models are not designed to take economic factors into account, so that the choice of alternative management methods to be tested reflected a variety of different economic objectives. The study showed that climate change had an important impact on stand growth under the alternative management strategies and that establishing species better adapted to climate change had substantial impacts on harvestable biomass. Subsequent studies (McCarl et al. 2000) using management models with economic objective functions have demonstrated similar results, highlighting the importance of adaptive management.

The information that management models can produce about the economic impacts of climate change and adaptation to it are substantial and include, in addition to harvest levels and information about the size and structure of forest stocks, such things as harvest revenues over time, the net income from harvests over time and the value of land as determined by the flow of net income from these harvests over time. But, management models have at least three important weaknesses from the standpoint of estimating economic impacts. First they apply to just a single stand, or plantation or perhaps forest. The geographic and forest species coverage is generally limited. Second, the prices of timber in the current and future periods are determined outside the model. It is not an output of these models. The problem with this is that it does not take into account the fact that climate change can have impacts on the supply- and demand-sides of national and global markets for timber and that this will influence market prices over time, exactly as in the agricultural sector. Third, management models apply only to timber supply and not to the demand for timber and wood products. Thus, they cannot simulate the impacts of climate change on consumer demand, consumption and the economic well-being of consumers.

To correctly simulate these environmental-economic interactions requires dynamic models of national and global timber and wood product markets in the forest sector.

Bio-Economic Sector Models

The term "bio-economic" is used here to reflect the fact that, as with agro-economic sector models, there is also a class of forest economic sector models that are linked to biometric models to determine the impacts of climate change on the growth (NPP) of the forest types in the economic model. The economic sector part of these models also falls into the same class of price-endogenous spatial equilibrium models as previously described for the agricultural sector. That is: they simultaneously solve for timber harvest levels and prices, production and consumption and trade flows between regions or countries in many different markets. Some of these models also include forward markets that use harvested timber and turn it into primary wood products. Therefore the discussion of these models is somewhat more limited than it would be otherwise.

There is, however, one very important difference between agricultural and timber market models. On any single piece of land trees are planted; they grow over time; and are harvested. This process goes on continually. As such, it is necessary to model the value of the timber harvests over time in both the product markets and the asset value of the stocks of trees. These two are linked by the fact that management decisions at any time in the life cycle of the forest stocks will depend to some extent on what the land owners think the trees and the land they are grown on will be worth in the future. To capture both market effects requires modeling the stock of standing timber as it evolves over time and is influenced by climate change and management (as is the case with management models), or take at least into account these interactions by indirect means.

Spatial equilibrium models of the forest sector can be broken down along at least two important lines: geographic coverage (national or regional vs. global) and how the product and forest stock (inventory) models are connected (dynamic, recursive, static). A dynamic linkage means that the model contains a representation of the forest inventory and simulates changes in forest stocks in every period due to growth, mortality and removals through harvests. This type of linkage between the economic and physical aspects of timber supply makes it possible to simulate dynamic decision-making, where management in any period depends on expected future periods. A recursive linkage is one where the model does not carry a detailed inventory break down, and does not simulate forest inventory development over time. Instead, the forest stock variable in the supply function of the model is updated after every harvest. This approach leads to myopic decision-making, since only the forest stock in the previous period influences simulated forest management in the current period. A static linkage is one that has no linkage between the supply-side of the model and the forest stock; however production is limited by the availability of land.

Table 3.3 shows a Breakdown of Spatial Equilibrium Forest Sector Models along these two dimensions. The list is not perfectly complete, but does represent closely the state-of the art in forest sector economic modeling.

The two FASOM – Forest and Agricultural Sector Optimization Models – and the GLOBIOM – Global Biomass Optimization Model – in Table 3.3 have an additional feature that is not shared by the other models, namely: they include both the agricultural and forest sectors and explicitly model the competition for land between these two sectors. As such all three of these models can be used to simulate mitigation of greenhouse gas emissions in both sector, the impacts of climate change and adaptation to these impacts, and the interacting effects of the two. The forest sector in both the US- and EU-versions of FASOM is linked to the agricultural sector in each model by a common land and in the objective function. The models can be run as single- or two-sectors models. The two sector versions are particularly effective in modeling the impacts of climate change on carbon sequestration and the cost of sequestering carbon on forest and agricultural lands to offset greenhouse gas emissions (Adams et al. 1999).

As in forest management models, the simulated impacts of elevated CO_2 concentrations and climate change on the rates of growth of different forest types in these sector models is determined by biometric models. However, it is done on a multi-regional basis within the specific spatial domain(s) of the sector model. This has to be done, not only for the existing commercial species in each region, but also for other species, not currently grown, but which may be better adapted to climate change than the existing commercial species. The market part of these models then determines how these impacts are transmitted to timber and primary products markets as a result of shifts in supply and demand and long-term changes in timber stocks. In some cases, these models might foresee such a dark future for some species in some regions that large portions of these stocks are harvested immediately and replaced by species that are better acclimated to long term climate changes. In other cases, there might be very limited species substitution, but changes in management, such as shortening or lengthening of rotation ages, reducing/increasing stocking levels on regenerated stands, and changing thinning regime. In a two-sector model, such as US or EUFASOM, competition between the two sectors for land can also be affected, leading to substitutions between crop and timber land depending on the long terms profitability of each.

Table 3.3. Price Endogenous Agricultural Sector Models used to Estimate the Economic Impacts of Climate Change, Broken Down According to Geographic Coverage and Type of Linkage Between Timber Supply (Flows) and Timber Stocks

Linkages to Inventories Spatial Coverage	Dynamic	Recursive	Static/weak
National-Regional	USFASOM, EU FASOM, Sohngen-Mendelsohn	TAMM, SF-GTM	
Global	TSM Sohngen-Sedjo-Lyons Model	EFI-GTM,	GLOBIOM

USFASOM – United States: Adams et al., 1996
EUFASOM – European Union (under development): Schneider et al. (2008)
Sohngen-Mendelsohn – United States (Sohngen and Mendelsohn 1998, 1999)
Sohngen-Sedjo-Lyons Model. Global: Sohngen et al. (2001)
TAMM – United States: Adams and Haines (1980)
SF-FTH – Finland: Hänninen and Kallio (2007)
EFI-GTM – Global: Kallio et al. (2004)
GLOBIOM – Global (under development): Havlik et al. (2010)

The data requirements for forest sector spatial equilibrium models are fairly intensive. For example, the data requirements of the FASOM forest sector models include NPP/tree growth information from biometric models broken down for each species, region and management regime. They also need basic information about each management activity in the model: how much it costs to perform the activity, how it affects NPP, and what other primary resources (land, labor and capital) it uses. The parameters that determine the shapes of demand curves for timber (harvest price vs. quantity harvested) and primary products in these models must be estimated using historical data. Data about the size, age, and management structure of the existing inventory also is needed to correctly characterize the initial forest stocks in the FASOM models. The FASOM models are process models. There are no market supply curves in these models, per se. Instead these models use optimization techniques to select the economically optimal combination of management activities over time to apply, first, to the existing forest stocks and, after that, to successive forest inventories once the initial inventory is harvested. The TAMM and EFI-GTM models are also sector models, but they actually have explicit supply (and demand) curves in the models. The parameters of these functions are estimated using data sets on regional stumpage prices and harvest quantities. To simulate the economic impacts of climate change, all of the models shown in Table 3.3 require regional climate data to drive biometric models, which simulate changes in NPP, over space and time in the sector models. The sector models take this information and simulate how climatic change influences forest management, the size, location and structure of the forest stocks, the production and use of wood products, inter-regional trade in stumpage and wood products and the economic well being of wood producers and users in different regions, over time.

3.4. Current Capacity to Estimate Climate Change Damages in the Montenegrin Agricultural and Forestry Sector

An important point that was made in the introduction to this report, and which needs to be stressed again, is that because we say a country lacks the capability to assess the physical or economic damages of climate change doesn't mean that it lacks qualified people or lacks all the quantitative tools (models and methods) or data to assess some important aspects of climate change. Indeed, a major objective of this paper is to give examples of how some of the physical and economic impacts of climate can be assessed, now, in some sectors. The point is that analytical capacity is not something you have or do not have. It has to be measured along a continuum with reference to what is needed to take a certain analytical step and what exists.

3.4.1. Agriculture

The analytical capacity to simulate the economic impacts of climate change in the Montenegrin agricultural sector is not at all well-developed. This situation is discussed with reference to the three types of models covered in this study.

Crop Yield Models

We contacted several members of the agricultural faculty plus other experts and were told that there were no empirical (regression) models available to simulate the average annual yield of any commercial crops grown in Montenegro as a function of climatic and other variables. We also contacted a number of experts in the EU and US who are leaders in the field of agronomic modeling, plus specific EU experts who were familiar with the CERES and with the EPIC crop yield simulation. We also contacted a Croatian expert who helped provide information to the recent Croatian Human Development Report. None of these experts knew of any work going on Montenegro, which was based on the newer generation of crop simulation models. Local experts confirmed this.

Therefore, our conclusion is that there currently exists no model in Montenegro that can be used on short notice to simulate the effects of climate change in Montenegro on crop yields of important “row” crops. Note, however, that this does not mean that such a model could not be estimated (empirical) or calibrated (simulation) over a period of a year or so. Arguably, a well trained agronomist or agricultural engineer could learn how to implement either CERES or EPIC on a small number of row crops with a year of intensive effort and some training in centers of excellence for these models, such as the University of Madrid (CERES) and BOKU in Austria (EPIUC). Nor does it mean that the capacity does not exist to simulate some impacts of climate change on crops. The methodology used later in this chapter to estimate some climate change damages in the irrigated part of the agriculture was based on locally-prepared estimates of the impact of climate change on soil water balances.

Spatial Equilibrium Sector Models

We contacted international and national experts in the fields of agricultural market and agricultural sector modeling. From these contacts it would appear that there are no economic models currently available to simulate the physical and economic impacts of climate change on a single or multiple agricultural markets in the country, on short notice. However, it would be possible to develop this capacity over a period of roughly three years through a project involving a Ph.D or post-doctoral student.

Ricardian Models

Ricardian models to characterize the impacts of climate change on the agricultural sector do not require a lot of data and have been successfully developed in data-poor environments in Africa, Latin America and to a certain extent, China. Such a model does not currently exist for Montenegro. The difficulty that one often experiences in developing these models is that there is very limited agricultural land price data to use to create a comprehensive data set of land prices over different agricultural/climatic sub-regions and over time, as well. In most cases land prices must be inferred from existing information about net farm revenues, and when that information is not available it must be developed from the bottom up, based on production, cost and price data at the farm level. This can take a long time to assemble – often 3-5 years – if the African Ricardian models are any example. At the same, recent discussions among economists about the efficacy of this approach has required the models to become more sophisticated in terms of experimental design and statistical methods. So, it is not as easy to build the capacity to develop and implement Ricardian models in a “new” country as are the other models that have been looked at in this chapter. However, the fact that these models can provide some fairly rich insights into the economic impacts of climate change in data poor environments makes them attractive, even if they have limited policy use.

3.4.2. Forests

The capacity to simulate the economic impacts of climate change on the Montenegrin forest sector is also not very well developed. This situation is described with reference to the three types of models covered in this study.

Biometric Models

No such models exist in Montenegro, nor is there the local capacity to develop these models. There are no projects underway or planned to develop such models in the country or to team up with other global or EU forest institutions or organizations to calibrate an existing model to Montenegrin conditions.

Management Models

There are no stand uneven- or even-age management models in use in Montenegro. There are no growth and yield tables currently available to support this either. The development of up-to-date inventory of forest stocks will presumably provide the data for doing this. Forest scientists from Germany who are helping with the inventory project have shown an interest in developing an uneven-age management models for Fir, Spruce and Beech based on models developed for Bosnia. However, the model in its current form is not able to simulate tree growth for decades or even several years; it can not develop management plans; and does no optimization. A better plan would be start from the beginning with the new forest inventory and use these data to try to calibrate a simple growth model that fit the data and then build a stand management model around this growth model[15].

Spatial Equilibrium Sector Models

A sector model for the Montenegrin forest sector does not currently exist. A major question is whether such a model is needed given the relatively small scale of the operations in the forest sector. Initially, Montenegro may be better served by the development of better management models that can then be modified to include the capability to simulate the impacts of climate change on tree growth and then incorporate options to avoid/reduce these impacts in a management model.

Arguably, the Montenegrin forest sector is represented in the Eastern European/European region of the global forest trade models. But since Montenegro is such a small part of the large region in which it is contained, it would be difficult to allocate the results down to the national level. On the other hand the simulated economic effects of climate change on the forest sector in these other countries in Eastern Europe or Europe might be useful for formulating forest policies related to climate change in Montenegro.

3.5. Preliminary Estimates of Climate Change Damages on the Agricultural and Forest Sectors

3.5.1. Agriculture

The capacity to simulate comprehensive estimates of the economic impacts of climate change in the agricultural sector does not exist in Montenegro. However, it is still useful to see what we find out about the economic impacts of climate change using "back of the envelope" calculations. By exploring both the results obtained from these types of methods and looking at the methodological issues they raise, one can often build a better case for further development of analytical capacity.

For this sector, we implemented two different preliminary methodologies:

1. An investigation of the impacts of climate change on maize yields and revenues from maize production, using an existing study of crop yield damages from Croatia.
2. An investigation of the additional cost of pumping irrigation water to fruit crops that would be adversely affected by decreases in soil moisture and increases in crop water demands due to climate change.

15 Based on several personal communications with Mathias Dees and Axel Weinreich, April 20-28, 2010.

Impacts of Climate Change on Maize Yields, Production and Gross Farm Income from Maize Sales

A previously stated, the Croatian Human Development Report, *A Climate for Change* (UNDP 2008), relied on the work of Vucetic (2006) to make a preliminary estimate of the effects of climate change on revenues from the production and sale of maize. The same approach can be applied to Montenegro.

In her study, Vucetic used the CERES maize model to estimate the impacts of two different IPCC climate scenarios (SRES B1 and A2) using six different GCMs at several sites in Croatia. She showed that the net effect of climate change and the fertilization effect of higher CO_2 concentrations on maize yields would result in simulated yield reductions ranging from 3 to 8 percent in 2050 and 8 to 15 percent in 2100.

Data from Montenegro can be used to calculate how these yield reductions might possibly affect the production of maize and gross farm income in Montenegro. Table 3.4 shows the harvested area, average yield per hectare and total maize production for the period 2004 to 2008.

Table 3.4. Harvested Area, Average Annual Yield per ha and Total maize Production in Montenegro (2004 – 2008)

Year	Harvested Area (ha)	Average Yield (MT/ha)	Total Production (MT)
2004	3217	2.99	9641
2005	3059	3.16	9668
2006	2782	3.26	9066
2007	2756	2.52	6937
2008	2712	3.55	9625
Average	2905.2	3.096	8987.4
Source: Montenegro Statistical Office (2009)			

To measure the effects of climate change on maize production and gross farm income, it is first necessary to create a base case for maize production and prices for the years 2050 and 2010. However, it is very difficult to project planted and harvested areas on a year to year basis without a sector model due to changes in the relative profitably of crops as influenced by crop prices. The same is also true for year to year crop yield predictions due to climate variability without a crop yield model. Predicting both of these variables for 50 to 100 years in the future is even more difficult to do because of the need to factor in technological change. Finally, forecasting crop prices that far into the future requires taking all of these factors into consideration, not just in the Montenegrin agriculture sector, but in all of the countries capable of affecting food prices in Montenegro due to imports and exports. This is why agricultural sector models are so helpful. While the accuracy of making predictions so far into the future can always be questioned, such a model provides a tool for making all these calculations in a consistent and credible economic framework.

Perhaps the most straightforward thing to do for a preliminary analysis without such quantitative tools (i.e., crop yield and sector models) is to make the same assumptions that were made in the Croatian study, namely:

- The existing variation in crop prices over the last decade reflects the variation in real prices that will be seen in the future.
- All agricultural commodity prices change at the same relative rates over time.
- Average annual yields and harvested areas are fixed at 2004-2008 levels

The first two assumptions permit the existing variation in nominal maize prices to reflect the future variation in prices, removing the need to inflate/deflate maize prices. Average annual yields are held constant to make the impact calculations more transparent and easier for people to understand in today's terms. This assumption, also makes it unnecessary to decide how much of the change in maize production and gross farm income is due to climate change and how much is due to technological change. The existing planted area is held constant because it is too difficult to simulate what this would be in 2050 and 2100 without combining an agronomic and agricultural sector model.

It proved hard to obtain reliable data on crop prices in Montenegro in recent years because the country renewed its independence recently and previous estimates of crop yields were published jointly with the data from Serbia. For this study two sets of price estimates for maize were constructed, one using data on international trade prices for corn (USDA, 2004-2008) and one that was spliced together from an FAO (2010) data base for the period. Using these two sets of estimates, we estimated an average range of roughly 70 to 110 €/MT for international maize prices and 60 to 90 €/MT for domestic prices.

Table 3.5 shows the estimated impacts of climate change on maize production, using the data and assumptions described above. The range of estimated annual maize production losses is very small, with the losses ranging from -270 to -719 MT/yr in 2050 and -719 to -1348 MT/yr in 2100. These impacts are small, because maize production simply does not occupy very much land. However, damages would increase substantially, if current and future efforts by the government led to substantial growth in livestock numbers fed from corn, (and from small grains). This assumes a structural shift in the livestock sub sector, involving a switch from intensive grazing to intensive feeding of livestock over the next 50-100 years. So, for example, if corn area increased by a factor of 10 during this future period, the production losses would increase accordingly and the maize production losses would be on the order of magnitude of thousands to ten of thousands of tonnes.

Table 3.5 Annual Impacts of Simulated maize Yield Losses on Total maize Production in Montenegro

% Yld Change	Planted Area (ha/yr)	Average Yield (MT/ha/yr)	Production (MT/yr)	Production Loss (MT/yr)
2050 (-3%)	2905.2	3.096	8987	0
2050 (-8%)	2905.2	3.003	8718	-270
2100 (-8%)	2905.2	2.848	8268	-719
2100 (-15%)	2905.2	2.848	8268	-719

The losses in gross farm income shown in Table 3.6 are also quite small, ranging from -16,177 to -79,089 € in 2050 and -43,140 to -148,292 € in 2100. These estimates could be higher, if, as was just suggested, there were large structural shifts in the structure of the agricultural sector. But these are very difficult to predict without a sector model.

Table 3.6 Annual Impacts of Simulated maize Yield Losses on the Future Value of Gross Farm Income from maize Production in Montenegro (Change in Future Value of Gross Revenues/year)					
maize Prices (€/MT)	Gross Income, maize (€)	% Yield Reductions 2050		% Yield Reductions 2010	
		-3%	-8%	-8%	-15%
International 70€/MT	629,118	-18,874 €	-50,329 €	-50,329 €	-94,368 €
International 110€/MT	988,614	-29,658 €	-79,089 €	-79,089 €	-148,292 €
Domestic 60€/MT	539,244	-16,177 €	-43,140 €	-43,140 €	-80,887 €
Domestic 90€/MT	808,866	-24,266 €	-64,709 €	-64,709 €	-121,330 €

As emphasized, these economic damage estimates are very preliminary, but they are illustrative in two ways. First of all, they suggest that for climate change to significantly affect the economy of maize and probably the production of other grains, as well, the production of these crops will have to increase substantially in the next 50 to 100 years and this will have to involve major structural changes in the country's agricultural sector. Also the number and strength of the assumptions that had to be used to construct these estimates of economic impacts shows how important it could be to further develop the capacity to model the agricultural sector in an economic framework that takes into account the linkages between the environment, crop and livestock production, prices and consumer demand for food in multiple food commodity markets.

Impacts of Climate Change on Irrigated Agriculture: Increased Cost due to Increased Crop Water Demands

Montenegro's First national communication included estimates of how climate change would affect soil moisture and crop water demands. The idea behind this is that as temperature increases and precipitation decreases not only will there be less soil water for crops to grow, but the demand for this water also will increase. The net loss in soil water to meet the elevated crop water demand will have to be met by pumping additional irrigation water. This increased need for irrigation water can be translated into an economic impact if one considers the additional cost that farmers would have to pay to pump water. An increase in pumping will increase the cost of irrigated agricultural production and reduce the net farm income of irrigated agricultural producers. If it is assumed that yields will remain constant (because additional irrigation water matches the increase in crop water demand), then this additional cost would accurately capture the decrease in net farm income, which is a valid measure of welfare change and climate change damages.

The net crop water demand (in mm) was calculated at 22 locations in the country (See Figure 3.4) for four climate scenarios: a base case representing the current climate, SRES A1B (NF-Near Future: 2021-2050), SRES A1B (FF-Far Future: 2071-2100), and SRES A2 (FF-Far Future). Expert judgment was used to identify two categories of areas associated with the locations at which the calculations were carried out and to identify the amount of irrigated land in the two categories:

- Areas currently under irrigation
- Areas targeted for future irrigation

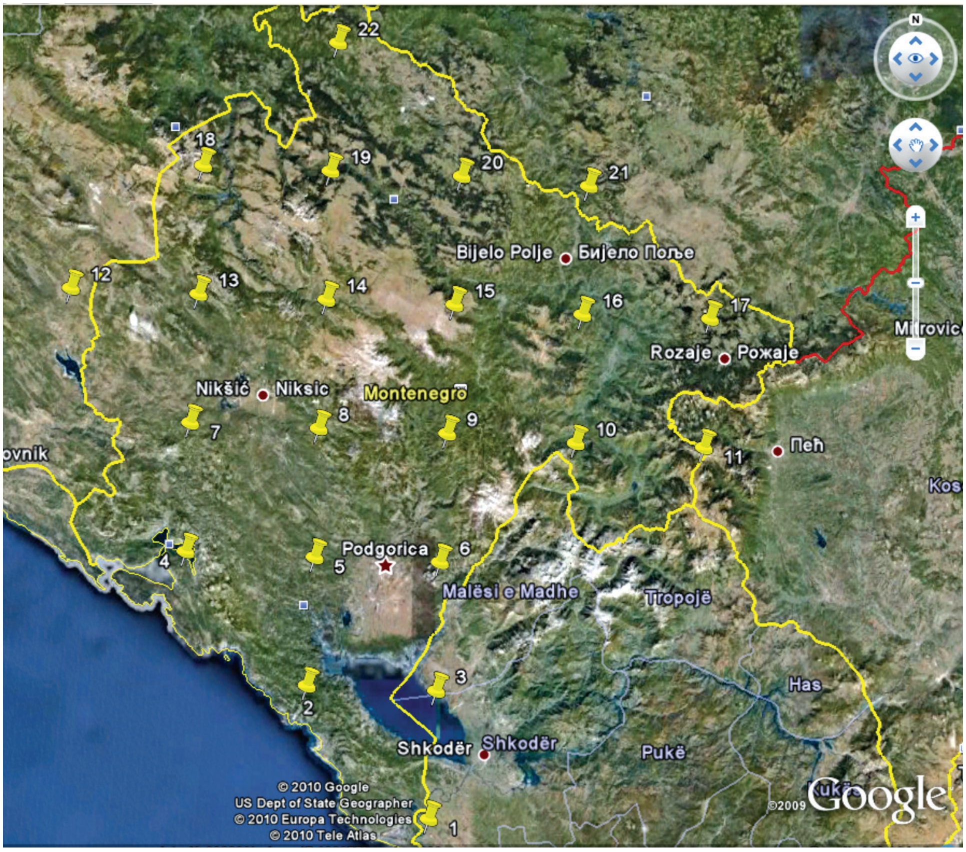


Figure 3.4 Locations in Montenegro where water balance and crop water demand calculations were made for Montenegro's First National Communication

Table 3.7 shows which areas were selected for each land category and the estimated cultivated area in each of these for the NF and FF periods.

Table 3.7. Irrigated Land Categories and Area used to Estimate Additional Irrigation Costs due to Climate Change in Montenegro

Land Category	Location Number	Area in Each Category and Time Period (ha)	
		Near Future 2021-2050	Far Future 2071-2100
Existing Irrigation	1 – 6	3000	3000
Planned Irrigation	7,8, 16,17,22	4000	5000

The change in the net crop water demand (in mm) for the period April – September (water season) in each area was calculated for all the climate scenarios for existing and planned (expected) irrigated land. The additional amount of irrigation water required during the water season due to climate change in each of the SRES climate change scenarios was calculated as the difference between the estimated water demand in the SRES scenario and the Base Case (Current Climate).

This estimate for each area was then converted from mm/yr to m^3/ha/yr and then scaled up by the areas in Table 3.7 to represent the annual amount of additional irrigation water (in m^3/yr) required to cope with climate change. A standard engineering formula was used to account for the electricity required (in Kwh/yr) to lift this water an average of 50 meters from the ground water table and distribute it to crops in the field using drip irrigation.

Finally, annual electricity use was converted to annual monetary costs (in €/yr) using information about current electricity prices in Montenegro. Electricity prices vary widely depending on the type of energy used, the time of day it is used, and the class of customer. In addition to marginal rates based on electricity use, customers are also charged monthly fees. Current electricity prices average around 0.06 €/Kwh/yr. If one wants to take into account future price inflation (and this, as has been stated is very risky) then prices could double or triple in the near future. To capture this we used two additional electricity prices to value the cost of pumping additional water: 0.15 and 0.25 €/Kwh/yr. As in the previous example, it is assumed that all prices inflate at the same rate over time, and therefore the nominal prices in the Base Case period reflect the real price of electricity in the future, without any need to inflate these prices.

The results of this analysis are shown in Table 3.8. While the amounts of land affected by the need to pump and distribute more irrigation water are relatively small (see Table 3.7), the damages in the far future period run into the millions of euros, depending on the climate scenario and the electricity price used in the analysis. For the A1B FF climate scenario, the future value of the cost of climate change to irrigators is between roughly 1.7 and 7.2 million €/year. In the A2 FF climate scenario, which is slightly more unfavorable in the existing irrigated area, the future value of the cost of climate change increases to between about 1.8 and 7.4 million €/year. For the A1B NF climate scenario, the future values of the costs of climate change are smaller on the existing irrigated areas than on the new areas. For the existing area the future value of the cost of climate change ranges from 58 to 241 thousand €/year. This is because the temperature increases in the NF period are smaller than in the FF scenario, and that is consistent with the overall results from the IPCC's most recent assessment (2007).

Table 3.8. Estimated Annual Additional Water, Electricity Use and Future Value of the Additional Electricity Used by Irrigated Agricultural Areas in Montenegro due to Climate Change in 2050 and 2010 in Montenegro

Land Category	Climate Scenario	Additional Water Use (1000 m^3/yr)	Additional Electricity Use (1000 Kwh/yr)	Cost of Additional Electricity at Three Different Electricity Prices (millions of €/year)		
				0.06 €/Kwh	0.15 €/Kwh	0.25 €/Kwh
Existing	A1B NF	1,513	965	58	145	241
New		-2,288	-1,461	-88	-219	-365
Total		-776	-495	-30	-74	-124
Existing	A1B FF	21,320	13,608	816	2,041	3,402
New		23,909	15,261	916	2,289	3,815
Total		45,230	28,869	1,736	4,330	7,217
Existing	A2 FF	23,786	15,182	911	2,277	3,795
New		23,909	2,246	855	2,136	3,561
Total		47,695	15,261	1,766	4,414	7,356

What is perhaps surprising is that, for the newly irrigated lands, less water is needed to meet crop needs than in the Base Case. This is because these new lands experience relatively larger increases in precipitation relative to increases in temperature as a result of climate change than in the areas of existing irrigation. The reduction in water use and electricity use therefore creates a potential benefit (i.e., negative costs) to farmers in these areas ranging from 88 to 365 thousand €/year. This phenomenon – where climate change actually creates benefits for farmers in the mid-21st century in some areas – is also seen some country studies of the United States and Europe (Adams et al. 2001; PASETA 2010; IPCC 2007).

The same sort of caveats and qualifications apply to this example of climate change damages as the previous one. The areal and sector-level coverage is very incomplete. The reduction in irrigation costs, assumes that crop yields will not decline (because crop water demands are satisfied) which may not be true if crop growth and development is adversely affected by higher temperatures, independent of water availability. If this is the case, then revenues from the sale of irrigated crops will fall and these losses, which are a part of the economic damages, will not be correctly accounted for, leading to an under-estimate of the damages due to climate change. However, despite these limitations, the results in this example are also instructive. They suggest that, in the future, more attention probably needs to be focused on the economic impacts of climate change on irrigated crops than on grain crops. By the same token, the analysis of these impacts needs to take into account the potential export value of these crops compared to their value in domestic consumption. To improve this type of analysis will require more detailed agronomic and agricultural sector models to look at the interplay between climate change and economic development in the agricultural sector.

3.5.2. Forests

There does not appear to be any information about the impacts of climate on the NPP/Tree growth rates of natural or commercial forests in Montenegro. The available forest models documented for Montenegro in the FODEMO II 2009 Forest Management Planning Manual[16] did not contain any functions that related NPP to climatic variables, which is understandable since the purpose of FODEMO is to characterize the size and structure of forest stocks. Also most of the private and public forests that are managed for commercial purposes are under un-even age management. Some published data is available to characterize the gross species and size class distribution of Montenegrin forests, but until the FODEMO data are available, this information was not adequate to calculate how management would respond to changes in climate with the time and resources available to the project

A preliminary analysis was conducted for even-aged pure beech stands. The idea was to determine how reductions and increases in average annual tree growth increments of 5, 10, and 20 percent would affect the optimal rotation age and timber land value. To do this type of analysis requires growth and yield tables for even age pure Birch stands, information about stumpage prices and management costs. These data can be used in conjunction with an even-age management (Faustmann) model to simulate the optimal rotation age for the stand and the net present value of all future harvests from that stand. Growth and yield tables for pure Beech stands in Croatia (Spiranec 1975) were available. Expert

16 FODEMO II 2009 Forest Management Planning Manual, Version 2. Podgorica/Freiburg, October - December 2009: See http://www.fodemo.com/fodemoresult2fmtools

information about the value of timber land and the growth and yield tables was used in conjunction with the management model to "back out" estimates of stumpage prices for different rotation lengths (75, 100 and 125 years). Yet, when these stumpage prices were plugged back into the management model to verify the Base Case, it was impossible to arrive at "reasonable" rotation lengths without making a number of assumptions. Specifically, the computed rotation lengths were far too short (20-50 years instead of 75-100 years), and the estimated land values were far too high. This could only occur if land owners in Montenegro are discounting their future earnings at very low discount rates (close to zero) and/or that profits from the sale of timber after deducting management costs are very low, and/or the growth and yield functions used in the analysis were not accurate. The likely source of this problem was the poor quality of the growth and yield table. However, as previously indicated, no growth and yield tables are available for Montenegrin conditions. At any rate, it was not possible to proceed any further with the data that was available to the study.

3.6. The Way Forward in the Agricultural and Forest Sectors

3.6.1. Main Findings

- Montenegro's analytical capacity to simulate the effects of climate change on both crop yields and the growth of natural and unmanaged forests using agronomic and biometric models is extremely limited.
- Likewise, there are no stand-level management models in Montenegro that can simulate the impacts of climate change on managed forest stands
- The analytical capacity to use and develop economic sector models for both the agricultural sector and the forest sectors is extremely limited.
- Finally, a macroeconomic model for Montenegro to simulate the impacts of climate change in the agricultural and forest sectors on important indicators of national economic development does not exist, nor does the capacity to develop and implement such a model.

3.6.2. Main Recommendations

- Short-Term (Next Few Years):
    - Once the new forest inventory data are available, an effort should be undertaken to develop stand level management models for important commercial forests. These models should be capable of simulating the growth of un-even and even-age forest stands and the transition between the two.
    - An effort should be made to train a small number of agronomists, agricultural engineers, and/or agro-meteorologists via contacts with Balkan and EU experts in this field.
- Long-Term (Five – Ten Years)
    - Undertake the development of an agriculture sector model for Montenegro that can be used in conjunction with newer crop yield models for development planning, management and climate change applications. This model can be tied to the existing EUFASOM model, and the sources of funding used to expand and refine it.
    - Undertake the development of a forest sector model in Montenegro. However, since the forest sector is quite small, it might make sense to do this first by expanding the functions of the stand management models from the stand level to the forest or species-level and then joining these models through a common land base. If a larger effort, based on EUFASOM, is undertaken, this would be best structured to take into account

the existing sources of funding used to expand and refine it.
    - o Undertake to develop a center of excellence and/or university department that combines agricultural, resource and environmental economics to help support long term development planning and management in the country and to conduct studies of the economic impacts of climate change in this sector.
- Cross-Cutting (Applies to virtually all sectors)
    - o Undertake to develop a macroeconomic model for Montenegro. This model should be developed with some care so that the data "entry points" in each sector to simulate development impacts and consequences are consistent with Montenegro's own sector level development policies and economic structure.

4. CLIMATE CHANGE DAMAGES IN THE TOURISM SECTOR

4.1. Introduction: Background and Objectives

4.1.1. Background

Tourism plays an important role in Montenegro's economy. A recent study by WTTC (World Travel and Tourism Council 2009) estimated that 10.5% of 2009 GDP would be generated through direct effects of tourism industry, while direct employment in the sector was expected to account for 9% (14,700 jobs) of total employment. When direct and indirect effects are added together, tourism was expected to account for 20.8% of the national GDP and 17.8% of total employment for the same year, making up more than 40% of country's total exports.[17]

Historically, tourism has also played an important role in the economy and represented one of the country's main exports. This was especially evident in the 1980's when visitation reached its highest levels. In the period 1985 – 1987, some 10 – 11 million overnights were recorded annually, with roughly 1/3 of total overnights made by foreign tourists. Direct income (domestic expenditures by tourists) from tourism approached US$ 100 million per annum. Visitation slightly declined by the end of the decade, and following the culmination of the crisis in former Yugoslavia and breakout of several wars in the region during 1990's, the tourism industry experienced a sharp decline. An overview of the number of overnights and structure of visitation[18] for selected years over the past three decades are shown in Figure 4.1.

17 Estimations made based on the methodology for Tourism Satellite Accounts (TSAs). The WTTC report *Travel and Tourism: Economic Impact Montenegro* was published in July 2009.

18 For comparison purposes, structure of visitation is analysed for the three main emitting markets: Western and Eastern Europe, and the region of former Yugoslavia (including Montenegro i.e. domestic tourism). Traditionally, visits from non-European countries have been low (below 1% of total).

	1986	1989	1998	2008
Western Europe	2,799	2,396	72	880
Eastern Europe	829	593	158	1,944
Former Yugoslavia (incl. MN)	7,254	6,916	4,298	4,905

Figure 4.1 Overnights by the main emitting markets in the period 1986 – 2008 For selected years

The conflicts and economic downturn of the 1990's had a detrimental impact on the entire economy and tourism in particular, whereas the beginning and the end of the decade (the later due to Kosovo crisis) were particularly bad periods in terms of visitation and income. In 1991, for example, revenues from tourism fell below US$ 7 million as compared to the levels of 70 to 100 million US$ earned annually in the period 1987 – 1990. In 1999, the number of tourists had declined more than 50 percent compared to 1998. For much of the 1990's, tourism was limited to domestic tourists and few regional source markets (predominantly Serbia, to lesser extent Bosnia and Herzegovina and Macedonia), and mainly linked to short summer seasons/ coastal tourism.

As the region stabilized and domestic efforts to revitalize the sector intensified, a gradual increase in visitation and revenues was recorded in the first half of 2000's. In the period 2005 – 2008 (prior to global economic crisis) tourism experienced a rapid increase and was generally seen as one of the main drivers behind the overall economic growth in the country[19]. Changes in the recorded number of tourists (foreign, domestic and total)[20] over time are shown in Figure 4.2. In analyzing the scope and effects of tourism industry in Montenegro, it is common to inflate recorded visits by 5 – 10% due to unregistered visits – mainly by tourists that spend their holidays in rented or owned apartments and houses.

19 In 2006 and 2007, GDP growth rates were 8.6 i 10.3% respectively.

20 Categories 'foreign' and 'domestic' tourists shown in Figure 4.2 changed over time with changes in Montenegro's state status. In the period prior to breakdown of former Yugoslavia (1980's and the very beginning of 1990's), visitors from currently independent countries of the region – including e.g. Slovenia, Bosnia and Herzegovina etc. – were recorded as 'domestic' tourists. In the period 1992 – 2006 category 'domestic' tourists referred to visitors from Serbia and Montenegrin tourists. Since 2007, following the renewal of independence, only Montenegrin citizens are recorded as 'domestic' tourists.

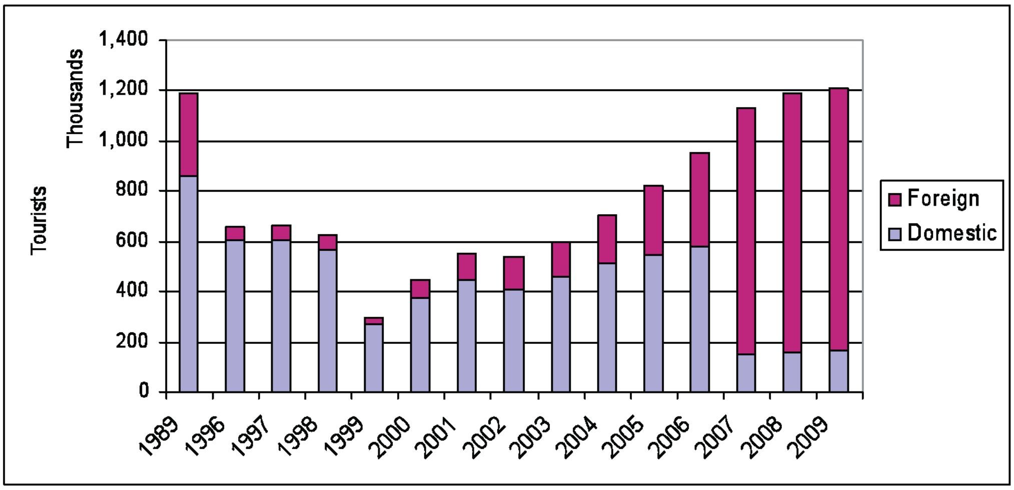


Figure 4.2 Number of tourists (1989 and 1996 – 2009)

The predominant share of tourism – up to 91% of all visits and as much as 96% of the total number o overnights – over the past 10 years is linked to coastal region[21], as illustrated in Figure 4.3.

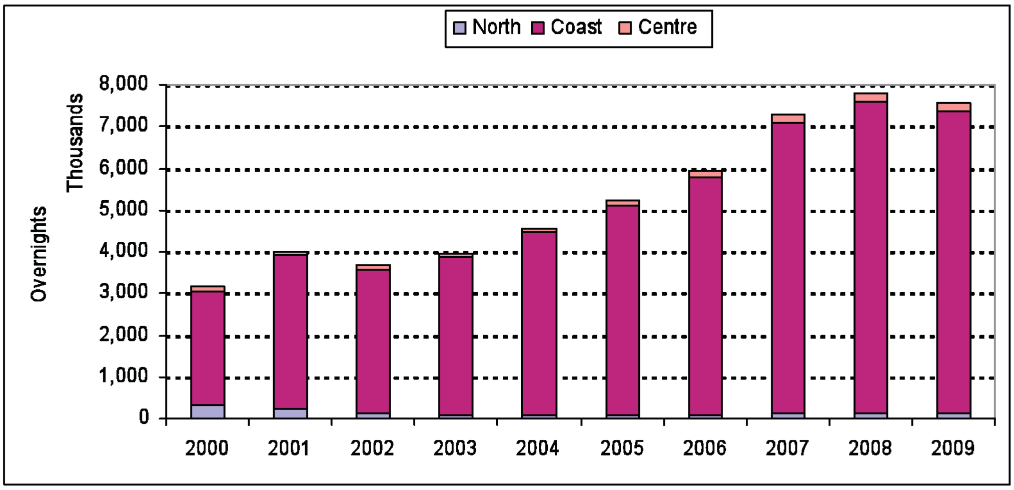


Figure 4.3 Distribution of Tourist Visits by Region

The prevailing concentration of coastal tourism, shown above in Figure 4.3 has a direct impact on the temporal distribution of visits during the year. According to the Strategy for Tourism Development in Montenegro until 2020 (the Strategy was adopted in 2008, as an update of the 2001 Tourism Development Master Plan), close to 70% of all overnights in recent years take place in July and August i.e. close to 90% in the period June – September. The concentration of summer visits has at least two undesirable consequences. The first is that the sea-side communities experience large seasonal swings in income, employment and unemployment. These are predictable, but nonetheless worrisome from the perspective of social costs and human development. Second, this leaves the national economy very vulnerable to climate change, which is predicted to result in decreases in coastal tourism in Southern Europe (but increases in tourism to Northern Europe) due to excessive day-time temperatures (PESETA 2009). Mountain tourism (both winter and summer) is receiving increased attention during the past few years yet its contribution to the overall tourism remains low. But winter activities will also be

21 Visitation (numbers of tourists and overnights) is recorded by municipality; summing up municipal numbers for the three regions in Montenegro – coastal, central and northern – is used to estimate levels of coastal and mountain tourism in this study.

vulnerable to projected increases in rainfall (instead of snowfall) and warmer winter temperatures (MSPEP 2010)

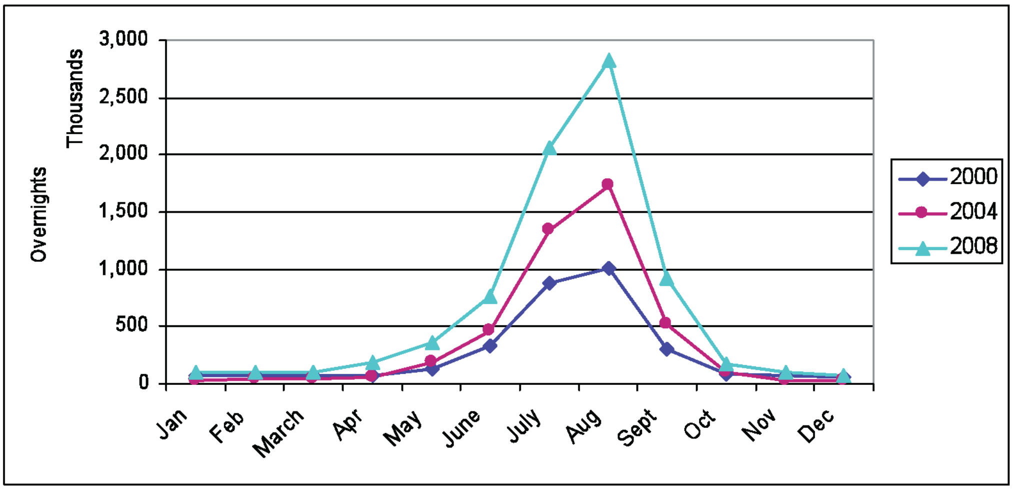


Figure 4.4 Distribution of Coastal Tourism by Month

4.1.2. Objectives

This chapter has four main objectives. First, Section 4.2 summarizes how the tourism sector in Montenegro may be affected by climate change. Second, in Section 4.3, it describes the methods available for estimating the economic value of future climate change damages in the tourism sector. Third in Section 4.4, it evaluates the current capacity that exists in Montenegro to estimate the economic value of climate change damages in the Tourism sector. Fourth, in Section 4.5 it provides very preliminary estimates of the economic value of some of the climate change damages that can be calculated, now, given the information available to this study. Finally, in Section 4.6 it suggests ways to develop the analytical capacity to estimate climate change damages in the tourism sector and the institutional capacity to use these estimates to make policy in the public and private sectors related to the development and regulation of the tourism industry.

4.2. Potential Impacts of Climate Change on the Tourism Sector

Estimating the climate change damages to the tourism and recreation sector is complicated theoretically from two different angles. First of all, this is one of those areas of modeling where it is hard to disentangle the human, adaptive response to climate change from climate change damages. This is because, tourists can be expected to adapt autonomously (i.e., without any action by governments) to climate change by changing some combination of the places they visit, the seasonal timing and lengths of their visits, and the tourism-recreational activities they engage in. By adjusting their behavior in these ways, individual tourists can avoid climate change damages. However, since we only observe the tourists flows after these adjustments, getting back to the climate change damages without any adjustment is computationally tricky.

In fact, all of the top-down estimates of the effects of climate change on tourism and recreation view the adaptive responses of individuals to climate change (in the form of changes in their travel behavior) as the impacts of climate change, and not adaptation. Parenthetically, all of the welfare losses that have been estimated in these studies include the net benefits of these adjustments and so overstate climate change damages.

Second, the adaptation of tourists to climate change will not be without irony in some cases, since adaptation that improves the welfare of tourists (if they go elsewhere or spend less locally) may decimate a local economy with additional negative multiplier effects into the national economy. Thus, the effects of the impacts of climate change in this sector on regional and national income accounts will probably be much more important from a policy perspective and may even be in a different direction (minus rather than plus) than the impacts on tourists , the majority of whom come from outside national boundaries.

The IPCC Fourth Assessment Report's coverage of tourism and recreation is poor. It only includes the European literature on the effects of climate change on tourism and recreation and almost totally ignores the vast literature of recreation demand that underlies almost all of the quantitative impact studies in this field. Table 4.1 represents an attempt to make some generalizations about the physical impacts of climate change and their implications on the behavior of tourists.

Source of Impact	Type of Impact
General changes in climate and weather • Effects of increased temperature on beach and lake tourism • Effects of increased temperature, reduced snowfall and more rain on skiing opportunities • Effects of changes in the frequency and magnitude of floods and droughts	Directly affects the attractiveness of a location and/or its suitability for different forms of recreation for tourists and indirectly affects many specific environmental characteristics of locations, including vegetation, animal populations, and scenic amenity values which also influence tourism and recreation opportunities in various ways.
Precipitation and temperature-induced changes in the discharge of streams and lake levels	Indirectly affects: • the attractiveness of a location for tourists • structure and development of aquatic ecosystems and habitats that influences the supplies of environmental services enjoyed by tourists
Precipitation and temperature-induced changes in water quality	Indirectly affects: • the attractiveness of a location for tourists • structure and development of aquatic ecosystems and habitats that influences the supplies of environmental services enjoyed by tourists
Temperature-induced changes in water temperatures	Indirectly affects: • the attractiveness of a location for tourists • structure and development of aquatic ecosystems and habitats that influences the supplies of environmental services enjoyed by tourists
Sea-level rise induced changes in salt water levels, salt water quality and temperatures	Directly and Indirectly affects: beach recreation opportunities tourism infrastructure structure and development of coastal aquatic ecosystems and habitats that influences the supplies of environmental services enjoyed by tourists

Table 4.1 Summary of Potential Impacts of Climate Change on Tourism and Recreation

First of all, there is a reasonably large body of empirical literature that confirms that individuals have preferences for climate and that this influences where they live and where they travel as tourists (Loomis and Crespi, 1999; Mendelsohn and Markowski 1999; Maddison 2001; Lise and Tol 2002; Hamilton 2004; Richardson and Loomis 2004). In that sense, differential changes in climate and weather – whether environmentally harmful or beneficial or neutral – will have differential impacts on the places where people travel as tourists in the short-run and possibly where they live in the long-run.

Climate change can also have indirect effects on tourism and recreation to the extent that it affects the non-climate tourism and recreation services provided by the natural and built environment. For example, climate change may improve or degrade an aquatic ecosystem, affecting sport fishing recreation opportunities (Ahn et al. 2000) or it could influence access to mountain trails, the health and appearance of mountain meadows and opportunities to observe wildlife in Alpine settings (Richardson and Loomis 2004). Apart from the damages these climate change impacts may have in other sectors, they also have the potential to influence tourism flows and activities in complex ways, benefiting some places economically while hurting others due to changes in local tourist expenditures and the multiplier effects through the larger economy.

In Montenegro, the most important climate-related impacts on tourism and recreation (other than sea level rise) will probably be related to the effect of climate change on air temperatures both at coastal resort locations in the summer and mountain ski resorts in the winter, along with the increase in winter rainfall in the mountains that will adversely effects skiing. Tourism will also be affected by the impacts of climate change on river discharges and lake water levels, fresh water quality and temperatures, all of which have the potential to influence the flow of market and non-market services provided by the natural and built environments to tourists. Karst aquifers may be particularly vulnerable, since even small reductions in precipitation can reduce runoff and impair the scenic quality of the sites/formations where they come above ground. The timing and extent of sea level rise will also have potentially important impacts on tourism opportunities along the coast. This includes impacts not just on beach recreation activities, and coastal fishing, but also on activities related to non-consumptive tourist use of the environment through costal bird watching and hiking and also impacts on amenity values associated with visual changes in "the scenery". These types of impacts can be expected to further influence the behavior of tourists in ways that could help or hurt the national and local economies.

4.3. Approaches and Data Needs for Valuing the Physical Impacts of Climate Change

The impacts of climate change and sea-level rise on tourism and recreation have two economic dimensions that were presented in Chapter 2. The first involves estimating the welfare changes experienced by individual tourists as a result of the physical impacts of climate change on their travel and recreation behavior. The estimated value of these welfare changes will depend on how we treat autonomous behavioral adjustments to climate change by individuals (changes in where they go) - either by excluding these adjustments in some way to get at a measure of climate change damages or by including them to arrive at a measure of residual or imposed climate change damages[22]. The second dimension involves estimating the effects on the local and national economies of changes in expenditures on tourism and recreation in Montenegro as a result of climate change and sea level rise.

22 As indicated above, by not allowing adaptation to influence the calculation of climate change damages, these damages will always be greater in absolute terms than the imposed climate change damages and the difference between the two will reflect the net benefits of adaptation.

These are entirely different measures of economic damages. The first is consistent with applied welfare analysis, while the second is consistent with national income accounting. Both measures have a place in the policy dialogue, but as we cautioned previously should not be added together[23].

4.3.1. Ricardian Analysis

One approach that could be used to simulate the effects of climate change and sea level rise on tourism and recreation is Ricardian analysis developed by Mendelsohn et al. (1994), which was discussed previously in relation to impacts on the agricultural sector. To our knowledge this approach has never been tried to estimate economic impacts of climate change, but it would make economic sense to do so. Most recreation activities use land (although not all of it is private) or lie adjacent to private land and buildings whose values will potentially be influenced by climate change. Golf courses, camping sites, put-and-take fisheries, ski resorts, beach-front development all come to mind as inputs to the supplies of different types of recreation opportunities that may be affected by climate change. For example, if sea level rises or if there is much less snowfall at ski areas, tourism operators at these sites will experience lower profits and this will be reflected in long-term property values of beachfront property and ski resorts.

Thus, it would seem possible to estimate some measure of the damages due to climate change and/or sea level rise by using aggregate or individual cross sectional panel data to estimate the parameters of a Ricardian land rent function (model) for different types of resort- and recreation-based property, as shown in the previous section on agriculture. This model would seek to explain the variations in resort property asset values (such as for ski areas) as a function of climate and control variables. Once the model parameters were estimated one could use the function to simulate the change in land values by evaluating the climate variables with information from downscaled IPCC climate scenarios and comparing these simulated land values with those in the base case.

The resulting changes in land values derived from such models may not be consistent with climate change damages, as we have defined them. This is because the data on land values used to estimate the model's parameters will almost certainly include the adjustments that land owners and tourists make to climate variability. As a result, the simulated changes in land values will include the effects of adaptation to climate change. Consequently, these models may be used to provide estimates of imposed (residual) climate change damages, but not strictly speaking estimates of climate change damages. On the other hand, this approach should take into account all kinds of adjustments – direct as well indirect – to the impacts of climate change and thus give more accurate estimate of the imposed climate change damages. The trick is how to use the Ricardian approach to decompose the imposed climate change damages into its two parts, climate change damages and the net benefits of avoiding these damages.

4.3.2. Travel Cost Models

Almost every approach used to estimate the effects of changes in the environment on recreation rely on the so called "Travel Cost" approach. The two main ideas that underlie this approach in its application to climate change are, first, that people's willingness to pay to travel to a recreation site is related to their willingness to pay for access to the site (Clawson and Knetsch 1996) and, second, that people's willingness to pay for access to a recreation site is based strongly on their preferences

23 Adding these estimates involves mixing benefits and costs. The welfare measure of damages specifically excludes changes in consumer expenditures in calculating consumer surplus losses, while the income accounting method includes them. To sum the losses together over-estimates both measures.

for certain attributes or characteristics of the site (Brown and Mendelsohn 1984; Willis and Garrod 1991). Putting the two ideas together means that people have downward sloping demand curves for some measure of the quantity of recreation they demand with respect to the site's access cost and that the quantity of recreation they demand will be influenced negatively by their travel costs to that site and by the climate at that site, although the relationship can be complex.

Travel cost models have been used to estimate the economic impacts of climate change on recreation demand and welfare in a number of recreation activities in the US using aggregate data (Mendelsohn and Markowski 1999), on visitation to a national park in the US (Richardson and Loomis 2004), trout fishing in the Appalachian mountains of the US (Ahn et al. 2000) and in the Northeast (Pendleton & Mendelsohn 1998), on skiing in the Northeastern US (Scott et al. 2006), and playing golf in the Metropolitan Toronto area (Scott and Jones 2006), to name most of the studies we are familiar with.

Travel cost models rely on either the observed or stated (contingent[24]) responses of individuals to climate variability to make inferences about how climate change will affect their behavior. There are many different types of travel cost models, depending on the underlying theory, the data used and the type of statistical methods employed to estimate the model parameters (Ward and Beal 2000; Ward and Loomis 1986). However, they all share the common characteristic that the individual's demand for recreation (as measured, usually, by the frequency of trips to recreation sites) is a function of the individual's demographic, social and economic characteristics, the exogenous characteristics of the recreation-related goods and services the individual consumes or enjoys at the site, and the time and money costs of travelling to the site and substitute sites[25]. This feature makes it possible to estimate the parameters of statistical models that embody these relationships and then use these models to simulate the effects of changes in on-site characteristics on recreation demand.

Because climate variables represent site characteristics, this approach lends itself nicely to assessing the impacts of climate change on recreation demand. These models can also, and have been used, to capture both the direct and indirect effects of climate change on recreation demand behavior (Richardson and Loomis 2004 and Ahn et al. 2000). Finally, because the demand models are derived from individual choice theory, they can be constructed in such way that they are structurally consistent with constrained welfare maximization and thus can be used to simulate the impacts of changing the climate variables and the indirect impact variables (both of which are site characteristics) to reflect the information in downscaled climate scenarios. Unlike the Ricardian method, travel cost models can be used to estimate not only the imposed damages of climate change, by allowing individuals to adjust their behavior in response to climate, but also climate change damages, by holding the measure of recreation demand constant and varying the climate. Finally, because the travel cost method measures changes in recreation demand, it is possible to use this approach in conjunction with other data to simulate changes in recreation participation and merge these data with on-site information about expenditures to come up with estimate of the impacts of climate change on tourism and recreation expenditures. However, as we previously noted, these impacts can not be meaningfully added to welfare losses, as to do so represents a form of double counting[26].

24 Contingent methods include asking individuals how much they are willing to pay to avoid climate change damages and/or how they would change their trip behaviour in the face of a specific change in climate. The replies to these questions reveal "stated preferences" which may not coincide with observed or "revealed" preferences that are reflected in changes in actual behaviour.

25 The importance of including the "prices" of substitute sites has been demonstrated by Rosenthal (1987); however none of the travel cost models used to simulate climate change have included inter-site substitution in the model structure. The substitution that occurs in these models is strictly due to the effects of climate on participation aggregated across sites.

26 In fact some simple algebra can be used to demonstrate (although we do not do so here) that adding together consumer surplus changes and expenditures changes is equal to the change in willingness-to-pay due to climate change, which overstates the welfare

It is instructive to note that none of the existing studies of the impacts of climate change on global tourism have used travel cost models. These studies are based on "participation models".

4.3.3. Participation Modeling

A participation model is like a travel cost in some ways. It is regression model whose structure and parameters explain the variation in a measure of recreation demand in terms of the variation in exogenous variables. However, the travel cost model is derived from economic theory and, like demand for conventional market goods and services, includes price variables associated with the recreation opportunity being demanded and its substitutes. Participation models, on the other hand, exclude measures of travel costs as independent variables. Also, participation models are somewhat more flexible than travel cost models when it comes to measuring participation, including usually both the intensity and duration of participation through such measures as "recreation days" or "overnight stays".

Participation models have been used in both global and national assessments of the impacts of climate change on tourism and recreation. The most widely used model to date is the Hamburg Tourism Model (HTM) developed by Hamilton and Tol (Hamilton et al.2005A and 2005B; Bigano et al. 2007), which accounts for the impacts of climate change on both domestic and international tourism. This is a global model, but the parameters of the participation model were not estimated using data from Montenegro. Pieces of such model are used in Section 4.4 to estimate the climate damages for Montenegro. Another global study of tourism was the recently included the PESETA (Projection of Economic impacts of climate change in Sectors of the European Union based on boTtom-up Analysis) study (JRC 2009), using a slightly different approach to participation modeling. This study actually included Montenegrin data, but the results for Montenegro were not included in the Final report or any of the technical reports from this project. These data were also used in Section 4.4 to estimate climate change damages in the tourism sector for Montenegro.

Participation models, like travel cost models, could be used to simulate the impacts of climate change on different types of recreation in Montenegro. The models, which could be general to the country, or site specific, or include multiple sites would have to be estimated on panel data from surveys of individuals or aggregate cross-section (and time series, if available) data at the national or sub-national level. These models Participation models could be used to simulate the impacts of climate change on tourism and recreation participation in the same way as with a Ricardian or travel cost model. That is: by evaluating the regression model(s) with data on the control variables to take into account both the distribution of trips by tourists with different individual characteristics and the non-climatic site characteristics and data on climate change from downscaled IPCC climate scenarios. With this information it would be possible to simulate both a reference climate scenario and any number of climate change scenarios. The effects of climate change on participation at the site are found by comparing the simulated changes in participation associated with the climate scenarios with the results from the reference case.

A major practical difference between travel cost and participation models in climate change research is that travel cost models can be used to directly estimate effects of climate change on losses of welfare by tourists. Participation models, on the other hand, can't provide economic welfare estimates by themselves, but can be used with per unit benefits estimates from other studies to simulate both

change by an amount equal to the change in expenditures (when climate change causes net welfare damages).

welfare (i.e., damage) and expenditure impacts. This is the case with all of the studies using the HTM model and also for the PESETA study. In both these and other studies, per capita tourist expenditures (or some variation in this measure) are used as the unit valuation measure that is applied to the change in the number of tourists or the number of overnights.

4.3.4. Data Needs for Ricardian, Travel Cost and Participation Models

The models that we have discussed in this chapter are all empirical, based on regression models. That is: they are single or, in some cases, multi equation regression models whose parameters have to be estimated using the appropriate data to explain the variation in a dependant variable (tourism and recreation land values for the Ricardian model and recreation demand and participation, respectively, for the travel cost and participation models, as a function of the variation in control and climate variables. Once the parameters of these models are estimated using regression techniques, they can be used to simulate the physical and economic effects of changing the values of the climate variables to fit specific IPCC downscaled climate scenarios and the control variables (to take into account different locations and populations). There are differences between these models, and we have highlighted many of the most practical ones, but because these models are more similar then dissimilar, they can be treated as a single group in the following discussion.

The parameters of these models can be estimated using aggregate cross-sectional data or cross-sectional panel data constructed from surveys of individuals. For the Ricardian model, the aggregate data could be based on cross-sectional information at the sub-national level about the value of golf courses, or ski-resorts, or beach-front resort property, etc., with climate and control variables from the same sample units. The panel data for estimating a Ricardian model might be drawn from a survey of a large sample of individual resorts for one type of activity over a large area, including data about property values, control variables to reflect variations in the characteristics of the resorts, merged together with data bases about local weather and climate. However, since this approach has never been used to estimate the economic impacts of climate change on tourism and recreation, there may be many specific data issues that have as yet to be uncovered.

The travel cost model and participation model approach could be used (or tried) in Montenegro to explain a number of demand-related phenomena, such as: 1) travel between source and destination regions for tourism in general, or for a specific form of recreation or 2) tourism or participation in recreation in a single country, sub-national unit, specific multiple recreation sites that are substitutes for each other in one or more countries, or even at a single recreation site. The scope is quite broad, but the data bases vary. Aggregate, cross-sectional data bases, could be constructed for tourism flows between countries or sub-national units including those in Montenegro. It would also be possible to use existing, or construct new, data bases containing various measures of recreation demand/participation at the national and sub-national level. However, constructing new data bases is very resource intensive. These aggregate cross-sectional tourism/recreation data bases can be merged consistently with climate and socio-economic data bases to provide all but the travel cost data.

For travel cost models, travel cost data between sources and destinations have to be estimated from information about distances and modal costs. Estimating travel costs in an aggregate model of travel flows is complicated by the fact that there are as many travel costs (from source to destination region) as there are observations in the aggregate data base. Therefore, in any single equation travel cost model based on aggregate flow data it may only be possible to include a single "own" travel cost for each observation/origin-destination pair. In the case of travel cost models that are estimated using survey data taken directly from individuals, this "degrees of freedom" issue is not a problem. On the other hand, no existing travel cost study of the effects of climate change on tourism and recreation has investigated inter-site substitution related to differential travel costs. This, of course, is not an issue with participation modeling, which may better lend itself to the use of aggregate data.

In most recreation demand studies, the travel cost model is, in fact, used with cross-sectional panel data from reasonably large population surveys of individuals or households to explain recreation demand at one or a few sites. However, the more general conclusions that can be drawn from individual studies of recreation at a one, or a few sites, may be limited. Transferring results from a single study to a larger sample of sites is fraught with accuracy problems. However, if there are a number of similar studies at different locations, meta-analysis may provide accurate enough results for policy purposes (see the discussions by Shrestha and Loomis 2003). However, this type of approach is highly recommended for estimating the economic impacts of climate change on tourism and recreation demand at sites of international or national importance. In data-poor environments, benefits-transfer approaches are frequently the only alternative.

The data needed to simulate the economic impacts of climate change on tourism and recreation, once the parameters of any of these models is estimated, would consist of the existing data, that had already been collected, on the relevant non-climatic data variables plus climate data consistent with a specific climate change scenario. This data is not the same climate data used to estimate model parameters. Rather the data is taken from the results of GCM and RCM IPCC scenario simulations. These climate data then need to be down-scaled or re-scaled to fit the geographic units used in the tourism data bases. For aggregate data at the national level, this re-scaling has already been accomplished by most GCM-related climate centers. However, if the geographic sampling unit is a set of sub-national regions or if the study focuses on an individual or a few recreation sites, then the GCM/RCM climate results for specific scenarios must be downscaled to the geographic areas in which the climate influences tourism and recreation.

Finally, it is worth pointing out that tourism and recreation demand studies generally do not take into account the effects of economic development, as is true in many of the other sectors we are looking at. It is important to include the relevant aspects of economic development in some way in future studies of the impacts of climate change on tourism and recreation. This includes accounting for the growth in recreation demand, changes in future recreation opportunities due to economic growth and development and specific on-site effects, such as congestion. The effects of development are important to study because they interact with climate change in the future to affect the magnitude of the estimated damages and also influence the ways in which tourists and those in the tourism industry can adapt to climate change.

4.4. Current Capacity to Estimate Climate Change Damages in the Montenegrin Tourism Sector

This section will be brief. There currently do not exist any types of models to estimate the determinants of tourism and recreation behavior from empirical data at the local level. Discussions with economists and government officials in the relevant ministries did not indicate that there was anyone in the country who was trained to do Ricardian, travel cost, or participation modeling in the country. While this situation is not ideal, the lack of this type of specialized analytical capacity is not atypical in the Balkan region and many new entrants to the EU. If developing this capacity is thought to be important enough, the situation can be remedied by educating existing staff or new doctoral students in statistics and economics departments at Montenegrin research institutions in the development and application of these types of models. This may take a period of months (for particular courses) or a few years (in the case of doctoral students), but no longer.

The good news is that Montenegro does have the capacity to collect information about the travel and spending behavior of tourists to the country. This data is published in several places, most notably the Statistical Year Book, produced annually by the Montenegro Statistical Office (2009). This includes information about the number and country of origin of tourists entering Montenegro, as well as the types of resorts/destinations within the country they visit, their accommodation facilities, how much time they spend in the country engaged in various activities and how much money they spent in the country. All of this published information is broken down to account for both foreign and domestic tourists, and, as indicated, is often broken down by country of origin as well.

The most important aspect about this data is that the methods used to collect it and the definitions are consistent with global data bases such as those used in the HTM model and PESETA study. This means that, with a relatively small amount of effort (measured in person-months or perhaps a person-year) it would be possible to integrate Montenegro specifically into the existing structure of the HTM. Given some sort of project partnership between Hamburg University and a relevant research or government organization in Montenegro, this would make it possible to estimate the impact of climate change on tourism and tourism expenditures in Montenegro in a framework that takes into account how climate change will alter not only the recreation opportunities in Montenegro, but in other countries which may offer competing opportunities to tourists throughout Europe and even the world.

In the longer term, experience with the HTM could help develop the necessary experience by researchers and government decision-makers to develop and use more specialized data bases and sophisticated analytical methods to apply to in-country developmental needs. A good example of this would be a study of how climate change throughout Europe (not just Montenegro) would influence the development of the recreational skiing industry in Montenegro and the necessary public infrastructure to support it. The same types of methods could also be helpful, for obvious reasons, in the development of the beach tourism industry, not just from the standpoint of climate change, but also from the perspective of what demographic and income groups would be most attracted to Montenegro given different forms of tourism infrastructure.

Improving the capacity to analyze the economic impacts of climate change and to use this information to make public policy is not just a climate change issue, but a more general issue related to development and resource planning and management. Improving the capacity to analyze the physical and economic impacts of climate change on tourism will also improve the capacity to conduct development and natural resource planning and management in the sector for both the private and public sectors. This is the fundamental importance of what is labeled in this report "No regrets capacity building".

4.5. Preliminary Estimates of Climate Change Damages in the Tourism Sector

While the capacity to estimate the economic impacts of climate change on tourism in Montenegro is poorly developed, it is still possible to develop some preliminary estimates using existing models and data. The results have a number of limitations, but performing this type of "back of the envelope" calculation can help not only to point to some of the more robust general trends, but also reveal why better methods are needed to make more accurate estimates.

Two different modeling approaches were used to estimate the economic impacts of climate change on the tourism sector in Montenegro, as follows:

1. An investigation of the effects of climate change on tourism participation and expenditures, using selected information about the partial effects of changes in temperature on tourism arrivals and expenditures from the HTM model.
2. A similar type of investigation using the models developed for the EU PASETA project (2009).

4.5.1. Impacts of Climate Change on Tourism Arrivals, Overnights and Expenditures using Information from the HTM model

The HTM model predicts visitation by international tourists based on the area of the country, the length of the coastline, per capita income and annual average temperature (Hamilton, et al. 2005). Visits by domestic tourists are treated in roughly the same way (Bigano et al. 2007). This means that if one assumes that everything in the model is held constant in the HTM, except for the values of annual average temperature, it is possible to simulate changes in visitation by both groups using just information about the annual average temperature variable. For any given country, the area of a country and coastline length will not change, but per capita income will. In the HTM model an increase in per capita income will increase tourism, holding temperature constant. The focus of this study is only on the climate effect. This is because it is difficult to predict future changes in income. Also, by adding changes in per capita income, more uncertainty is added to the analysis. Moreover, if it is assumed that within 50-100 years all of the currently developed nations of the world will be experiencing roughly similar rates of increase in per capita incomes, then holding per capita income constant means implicitly that we are accounting for the growth of income in real, not nominal terms.

The HTM model was used to calculate partial changes in tourist visitation for international and domestic tourists under a range of average annual temperature changes from the Base Case average annual temperature. The input data and results used to make the economic calculations are shown in Table 4.2.

Table 4.2 Tourist Visits, Overnights, Tourism Revenues and Expenditures by Visits and Overnights for the period 2001-2008					
Year	Tourist Visits	Tourist Overnights	Tourism Revenues (Million €)	Expenditure/ Visit (€)	Expenditure/ Overnights (€)
2001	555,040	4,011,413	86	155	21
2002	541,699	3,689,505	148	273	40
2003	599,430	3,976,266	151	252	38
2004	703,484	4,561,094	180	256	39
2005	820,457	5,211,847	244	297	47
2006	953,928	5,936,270	308	323	52
2007	1,133,432	7,294,530	480	423	66
2008	1,187,492	7,793,280	552	465	71
Historical Average 2001-2008	811,870	5,309,276	269	306	47
Current Average 2007-2008	1,160,462	7,543,905	516	444	68
"High" (2 x current) Average	2,320,924	13,925,544	2062	888	148
Sources: Montenegro Statistical Office (2009); World Travel and Tourism Council (2009)					

The information shown in Table 4.2 illustrates once more the rapid increase in tourism that is occurring in Montenegro. This can be seen quickly by comparing the various averages for the total period with those for 2007 to 2008. Currently, most of this is driven by coastal tourism. Coastal tourism is expected to grow dramatically over the coming years. However, it is very difficult to project this growth because it depends on the growth of tourist infrastructure in other countries that can offer similar vacation opportunities to tourists as Montenegro and on the growth of per capita incomes in the countries of origin of tourists. However, using existing trends in the historical data to project tourism without accounting for other factors can lead to unrealistically high forecasts for both visitation and expenditures. A more complicated and realistic model of the impacts of economic growth on tourism and tourism expenditures is needed, but is not available. Therefore, the assumption used in the analysis of the economic impacts of climate change on the agricultural sector will be maintained by using the current estimates to reflect real as opposed to nominal values. However for illustrative purpose, future growth can be included in this analysis in a very simple – and not very accurate – way by conducting a sensitivity analysis three different values (historical, current, and high) to characterize the projected growth of tourism and tourist expenditures in future decades. For the medium (2007-2008 average) and high values we have arbitrarily chosen to inflate the average expenditures and visitation estimates by arbitrary factors of 2. These estimates are in the last three rows of Table 4.2

In the process of simulating the impacts of climate change on tourism and tourism expenditures, it was found that the results obtained from HTM, using the approach described above, are very sensitive to what the assumed average annual temperature is in the Base Case. It was decided to take this factor into account in presenting the results of the analysis, to show how big a difference it can have on the results. This kind of problem typifies economic analysis: models are often very sensitive to both assumptions and data, but it's hard to be sure if this sensitivity is real, or associated with model features, the assumptions built into the analysis or the data used to develop the model.

Table 4.3 shows the percentage changes in tourism visits and overnights that the HTM predicts for five different levels of temperature increases (due to climate change)1°C – 5°C for average annual temperatures ranging from 14°C – 17°C. The climate-related temperature changes reflect the range of changes in average annual temperatures in the A1B NF, A1B FF, and A2 FF climate change scenarios, while the range of average annual temperatures is used to show how sensitive the model results are to this variable.

The results illustrate how difficult it can be to estimate the impacts of climate change on human behavior due to a combination of model uncertainty/ sensitivity, uncertainty about the nature of climate change and even uncertainty about what the existing "real" average annual temperature is in relation to estimates of it based on the historical record. This problem is compounded considerably, using simple "back of the envelope" approaches. In general, there is greater certainty about the average annual temperature in the Base Case because we have historical data, be it limited, to measure that: somewhere between 15 and 17 degrees. Using this temperature range, the projected decrease in tourism could be as low as -1.73 percent or as high as -9.79 percent in the A1B NF case. For the A1B FF case, this range expands. Projected tourism losses could be as low as -5.19 percent or as high as -19.58 percent. The "worst case" projection occurs under the A2FF scenario where simulated tourist visits could fall by as little as -8.65 percent or as much as -24.47 percent.

Table 4.3 Simulated Climate Impacts: Percent Changes in Annual Tourist Visits for Different Changes in Temperature due to Climate Change and Different Estimates of Average Annual Temperature in the Base Case (% changes in annual tourism visits)

Ave. Annual Temperature (Degrees C)	Average Annual Temperature Increase due to Climate Change and Range of Climate Scenario Coverage				
	A1BNF	A1BNF	A1BFF	A1BFF & A2 FF	A2 FF
	+1 Deg C	+2 Deg C	+3 Deg C	+4 Deg C	+5 Deg C
14	-0.15%	-0.30%	-0.44%	-0.59%	-0.74%
15	-1.73%	-3.46%	-5.19%	-6.92%	-8.65%
16	-3.31%	-6.62%	-9.94%	-13.25%	-16.56%
17	-4.89%	-9.79%	-14.68%	-19.58%	-24.47%

Results are estimated using elasticities developed from the equations of the HTM model in a partial analytic framework

Table 4.4 applies the percentage changes in Table 4.3 to the estimates of tourist visits (Top Panels), and total expenditures (Bottom Panels) in Table 4.2, assuming the average annual temperature in the Base Case lies between 15 and 17 degrees and for three different levels of tourism and total expenditures.

Once again the projections of these impacts illustrate the problems associated with projecting when there are many sources of uncertainty in the models and data used in the analysis. The estimates of reductions in the average annual number of tourism visits ranges all the way from about -14,000/year to over -565,000/year, depending on the level of Base Case tourism and average annual temperature and climate scenario. The range of projected changes in expenditures is also large, between -4.7 € million/year and -504.6 € million/yr. However wide the range of the results may be, they are, nevertheless, instructive. They show that the largest single source of uncertainty lies in the projection of baseline tourist visits and expenditures by which to compare the climate change impacts. These types of projections are inherently uncertain, because they depend almost entirely on the level of tourism development in the next ten to twenty years, a period during which the effects of climate change on tourism are probably going to be very small.

The fact that a lot of the uncertainty in the projections in Table 4.4 is due to factors unrelated to climate and climate change does not mean that the climate change risk is negligible or that the estimates of the impacts of climate change, alone, on annual tourism visits and expenditures are also not uncertain. Even if the levels of visitation and expenditures remains at 2007-2008 levels, the range of tourism losses could be as low as about 20,000 visits/year and as high as about 284,000 visits/year, while the corresponding losses in revenues could run as low as about 9 million €/year or as high as about 126 €/year. With a doubling of both tourist visits and expenditures, the annual visitation losses would at least double and the annual revenue losses would at least quadruple, according to these projections.

Thus, even using a relatively simple methodology, the projections made here show that the adverse economic impacts of climate change on tourism expenditures will become a lot greater the larger the tourism sector. This suggests that the public and private sectors would benefit a great deal by planning for climate change, rather than ignoring it. This is especially true since the infrastructure associated with tourism – hotels, marinas, highways, etc – is relatively long-lived, and would cost more to "climate proof" after the infrastructure is built than include climate change considerations in the initial designs.

Table 4.4 Simulated Climate Impacts: Changes in Annual Tourism Visits and Tourism Expenditures Due to Climate Change for Five Different Changes in Average Annual Temperature due to Climate Change, Three Different Sets of Projections for Base Case Tourism Visits and Expenditures and a Range of Estimates for Base Case Average Annual Temperature

Visitation/Exp. Projections Ave Annual Temperatures	Average Annual Temperature Increase due to Climate Change and Range of Climate Scenario Coverage					
	Base Case	A1BNF	A1BNF	A1BFF	A1BFF & A2 FF	A2 FF
	+0 Deg C	+1 Deg C	+2 Deg C	+3 Deg C	+4 Deg C	+5 Deg C
Change in Annual Tourist Visits due to Climate Change (Total Annual Tourist Visits/year)						
Historical Average 2001-2008	Base Case Annual Tourists					
15° C	811,870	-14,045	-28,091	-42,136	-56,181	-70,227
17° C		-39,733	-79,466	-119,199	-158,932	-198,665
Current Average 2007-2008						
15° C	1,160, 462	-20,076	-40,152	-60,228	-80,304	-100,380
17° C		-56,793	-113,586	-170,379	-227,172	-283,965
"High" (2x current) Average						
15° C	2,230,924	-40,152	-80,304	-120,456	-160,608	-200,760
17° C		-113,586	-227,172	-340,758	-454,344	-567,930
Change in Annual Tourist Expenditures due to Climate Change (millions of €/year)						
Historical Average 2001-2008	Base Case Annual Expenditures (millions €)					
15° C	269	-4.7	-9.3	-14.0	-18.6	-23.3
17° C		-13.2	-26.3	-39.5	-52.7	-65.8
Current Average 2007-2008						
15° C	516	-8.9	-17.9	-26.8	-35.7	-44.6
17° C		-25.3	-50.5	-75.8	-101.0	-126.3
Projected High Ave.						
15° C	2,062	-35.7	-71.3	-107.0	-142.7	-178.4
17° C		-100.9	-201.8	-302.7	-403.7	-504.6

4.5.2. Impacts of Climate Change on Tourism Visits Using Information from the PESETA Project Tourism Methodology

Could the losses in tourism, both in terms of the average annual number of visits and average annual expenditures really be as large as projected by the simplified approach using information from the HTM model about the responsiveness of visitation to increases in temperature? To check this out, the same type of relationship was taken from the methodology used in the EU PESETA and applied to the Base Case visitation and expenditure data used in the previous section.

The PESETA methodology involved a two step approach to estimate changes in visitation. The first stage involved estimating monthly values of the TCI (Tourism Climatic Index developed by Mieczkowski (1985)) for each country in the Eurostat data base – including Montenegro – for a Base Case and a number of alternative climate scenarios. In the second stage, data from the NUTS 2 tourism data base was combined with information from the Eurostat data base to develop a monthly statistical relationship between tourism bed nights in a country and its TCI index, gross domestic product, and its consumer price index. It is fortunate that the unpublished data from this study about the computed monthly TCI values includes the monthly estimates of the TCI value for Montenegro for a Base Case and two IPCC climate scenarios (SRES A2 and B2) for two different regional climate models (HRHAM and RCAO). The information in the monthly statistical model about the partial relationship between bed nights and the TCI can be combined with the TCI values to compute the percentage change bed nights associated with a small change in temperature in the Base Case average temperature. This is the same type of "partial" methodology used in conjunction with HTM. An important difference is that the temperature data for the climate scenarios that is needed to compute a range of temperature increases from that base was "hidden" in the TCI index and, unfortunately, the original country data bases were not quickly available. Therefore the results for discrete temperature changes due to climate change can not be presented, only the results for the climate scenarios as a whole and the average annual temperature changes across all of Europe represented in them.

Another major difference is that in the PESETA study the TCI values and bed night statistical relationship were developed on a monthly, not an average annual basis. Thus, using the information from the PESETA study, it is possible to calculate the percent change in bed nights (and visitation if we assume the percentage changes are the same) due to climate change by month and by year for the four climate scenarios used in the PESETA study. The monthly results are not shown, here, but the percentage changes in visitation for Montenegro are shown in Table 4.5 for the average year (all 12 months) and separately for July and August.

The results in Table 4.5 illustrate at least three important things. First of all, projected tourist visits in July and August decreases in all four climate change cases. This is undoubtedly due to the sensitivity of this type of tourism to the existing variation in summer temperatures as reflected in the PESETA model. However, the annual average change in visitation shown in the table is always smaller than the June-July average change, and by implication the remaining 10 months of the year. In fact, the Hiram model projects increases in annual average visitation in both the A2 and B2 scenarios and small decreases in July and August while the RCAO model predicts average annual tourism decreases on the order of about 6 percent for the A2 and B2 scenarios and decreases of about -8 percent and -11 percent, respectively, for July and August in both the A2 and B2 scenarios. The Hiram model shows less sensitivity of tourism to climate change than does the RCAO model, but it is not possible to say why. What is possible to say is that both the annual and seasonal results of the RCAO fall roughly within the low and middle range of estimates shown in Table 4.4. Unfortunately, too much of the data used to construct the PESETA models were not readily available, so it was not possible to see how sensitive these results were on different estimates of the average annual and monthly temperatures, as was the case with the analysis using the HTM model information.

Table 4.5 Simulated Percentage Changes in Average Annual and Monthly Tourist Visitation from the PESETA Study due to Climate Change for Two Summer Months, Using Two Climate Scenarios and Regional Climate Models (% change in tourist visits/year)

Time Period	Climate Change Scenarios by Regional Climate Model and Average Annual Temperature Increase (for Europe)			
	Hiram – A2 +3.9 Deg C	Hiram – B2 +2.5 Deg	RCAO – A2 +5.4 Deg C	RCAO – B2 +4.1 Deg C
Annual Average	2.69%	2.86%	-6.43%	-6.49%
July Average	-0.25%	-0.03%	-7.79%	-7.87%
August Average	-0.33%	0.52%	-11.29%	-11.41%

It is likely that the tourist visitation in the HTM model largely reflects beach tourism, since this the overwhelming majority of tourist visits in Montenegro are to the coast. Thus, it is interesting to compare the reductions in visitation and expenditures simulated by the information taken from the PESETA models with those from the HTM model, using the same assumptions about the average annual number of tourist visits in the Base Case. In Table 4.6, the percentage changes in visitation from Table 4.5, using the PESETA methodology, are applied to the previous estimates of visitation and expenditures in the Base Case. The temperatures for July and August were averaged and the visitation rates in the Base Case were adjusted to reflect coastal visitation during July and August, using the average monthly weights for the period. The results are a Table with information that is somewhat comparable to Table 4.4.

When one compares the results in Table 4.6 for the PESETA analysis with the results in Table 4.4 for the HTM analysis, the main features that stand out are, first of all, that the projected visitation and tourist expenditures in Table 4.6 for the Hiram model in the PESETA analysis are not very close to the results for the HTM analysis in Table 4.4. However, the projected visitation and tourist expenditures in Table 4.6 for the RCAO model in the PESETA analysis overlap the low-end of the results for the HTM analysis in Table 4.4, even though the temperature changes and climate change scenarios are not the same in the two different analyses. Moreover, the RCAO A2 results for both visitation and expenditure losses in Table 4.6 fall in between the +4° C results (column 5 of the results) in Table 4.4 associated roughly with the A2 FF. The fact that the results of these two different sets of analyses partially overlap is not evidence that these projections are "accurate", but it does help to narrow the risk of making decisions about climate change policy.

Table 4.6 Simulated Climate Impacts: Changes in Annual Tourism Visits and Tourism Expenditures Due to Climate Change for Five Different Changes in Average Annual Temperature due to Climate Change, Three Different Sets of Projections for Base Case Tourism Visits, and Expenditures and a Range of Estimates for Base Case Average Annual Temperature

Visitation/ Exp. Projections Ave Annual Temperatures (Europe)	Climate Change Scenarios by Regional Climate Model and Average Annual Temperature Increase (for Europe)				
	Base Case	Hiram A2	Hiram B2	RCAO A2	RCAO B2
	+ 0 Deg C	+2.5 Deg C	+2.5 Deg C	+5.4 Deg C	+4.1 Deg C
Change in Annual Tourist Visits due to Climate Change (Total Annual Tourist Visits/year)					
Historical Average 2001-2008	Base Case Annual Tourists				
Annual	811,870	21,871	23,185	-52,170	-52,692
July-Aug	519,597	-1,552	1,550	-51,400	-51,914
Current Average 2007-2008					
Annual	1,160,462	31,262	33,140	-74,570	-75,316
July-Aug	742,696	-2,219	2,216	-73,470	-74,204
"High" (2 x current) Average					
Annual	2,320,924	62,524	66,280	-149,141	-150,632
July-Aug	1,485,391	-4,438	4,432	-146,939	-148,409
Change in Annual Tourist Expenditures due to Climate Change (millions of €/year)					
Historical Average 2001-2008	Base Case Annual Exp. (million €)				
Annual	269	7.2	7.7	-17.3	-17.5
July-Aug	172	-0.5	0.5	-17.0	-17.2
Current Average 2007-2008					
Annual	516	13.9	14.7	-33.2	-33.5
July-Aug	330	-1.0	1.0	-32.7	-33.1
"High" (2 x current) Average					
Annual	2,062	55.5	58.9	-132.5	-133.8
July-Aug	1320	-3.8	3.8	-130.4	-132.0

4.6. The Way Forward in the Tourism and Recreation Sector

4.6.1. Main Findings

- The capacity to collect and analyze tourism data in Montenegro is fairly good, but needs to be upgraded in the areas of projecting the determinants of tourism in various sectors.
- The ability to develop better tourism projections would be enhanced by the development of the capacity to estimate the parameters of travel cost and participation models, which is normally considered a sub-field of environmental economics called recreation demand modeling.
- Montenegro would benefit from co-operating with existing centers of expertise to include data from Montenegro in various global tourism models and to learn how to use these models.

4.6.2. Main Recommendations

- Short-Term (Next Few Years):
    - o Efforts should be made to involve Montenegrin experts with the work of existing centers of expertise in global travel cost modeling to improve the capacity to project tourism and tourism expenditures in Montenegro using global models
    - o An effort should be made to train economists broadly in environmental economics (and recreation demand analysis for this sector), both for conducting climate change impact and valuation studies, but also for assessing the economic impacts of many different forms of development on the environment.
    - o Finally, a macroeconomic model for Montenegro to simulate the impacts of climate change in the tourism sector on important indicators of national economic development does not exist, nor does the capacity to develop and implement such a model.
- Long-Term (Five – Ten Years)
    - o Undertake to develop travel cost and participation models to assess the determinants of international and domestic tourism in specific forms of recreation at specific sites in Montenegro both to project the economic impacts of climate change and, more generally, to assess development alternatives from an economic perspective.
    - o Undertake to develop a center of excellence and/or university department that combines agricultural, resource and environmental economics to help support long term development planning and management in the country and to conduct studies of the economic impacts of climate change in this sector.
- Cross-Cutting (Applies to virtually all sectors)
    - o Undertake to develop a macroeconomic model for Montenegro. This model should be developed with some care so that the data "entry points" in each sector to simulate development impacts and consequences are consistent with Montenegro's own sector level development policies and economic structure.

5. CLIMATE CHANGE DAMAGES IN THE WATER RESOURCES SECTOR

5.1. Introduction and Objectives

5.1.1. Background

Montenegro's First National Communication to the UNFCCC (Draft, MSPEP, 2009) does not contain a great deal of information about the water resources sector in the country or how vulnerable it is to climate change. Total average annual runoff from rainfall and precipitation is quite high in relation to the size of the country: it ranks in the top 4 percent of nations in the world in terms of runoff per geographic area. This is a somewhat misleading statistic, however. Certain parts of the country receive between 3200 and 4600 mm of precipitation annually, the highest in Europe. However, these areas are not heavily populated. As one moves toward the Adriatic coast, there is a sharp precipitation gradient and average annual precipitation in regions on or near the Adriatic coast can be as low as 650 to 750 mm, annually. Not surprisingly, then, only a small fraction of the runoff that runs through, or is generated in, Montenegro is used consumptively (municipal water supply, irrigation, etc.) or non-consumptively (waste water treatment, hydro-power, etc.). However, the fact that the demand for water resources and the surface water supply are misaligned geographically means that shortages in dry locations might be costly to meet if inter-basin transfers are required.

The main consumptive use of water in Montenegro is for the supply of settlements/ population. In 2005 and 2008, the latest years for which data are available, annual water abstractions in this category were 102 and 107 million m^3 respectively, whereas some 90% of total abstractions was from groundwater sources. Around 80% of population is connected to public water supply systems. The rest is supplied from small scale common and/or individual systems. Industry is the second largest user with average annual consumption of 49 million m^3 in the period 2004 – 2008. Industrial facilities predominantly rely on their own supply system (less than 3% of water used by industry is from public water supply systems) with roughly 2/3 of abstractions from surface and 1/3 from groundwater. Consumption of water by agriculture is extremely small. In 2009, the total irrigated area in Montenegro was only about 2200 ha and growing slowly. Most of the irrigated area is used to produce table and wine grapes, fruits and vegetables in the area starting from around Podgorica and running to the coast. Almost all of the water used to irrigate crops in Montenegro is drawn from groundwater and distributed by drip irrigation. For the period 2004 – 2008, annual irrigation water use has averaged around 6 million m^3 per year. Chapter 3 of this study, on the agricultural and forest sectors, examines the effects of climate change on water use by irrigated agriculture.

Finally, the most important economic use of water in Montenegro is to generate electricity. Between 2004 and 2008, water quantities used in hydropower plants ranged from 2.4 to 4.6 billion m^3. There are two large hydro-power plants in the country. HE Perućica has an installed generating capacity of 307 MW and average annual production of around 900 GWh. HE Piva has an installed generating capacity of 342 MW and average annual production of about 750 GWh. There are also an additional seven small hydropower plants, which have a combined installed capacity of 9 MW and average annual generation of 21 GWh. Currently only about 17 percent of the theoretical hydro electric generating potential is being utilized in Montenegro. The current Energy Development Strategy to 2025 includes plans for developing five large hydro-power plants (four on Moraca river, and Komarnica HE), with a total installed capacity of about 410 MW and several small hydro plants, with a total installed capacity of about 80 MW. Section 5.5 of this chapter provides a very preliminary estimate of how reductions in runoff due to climate change might affect the effective generating capacity of the plant located on the Piva River.

5.1.2. Objectives

This chapter has five main objectives. First, in Sections 5.2 it summarizes how the water resources sector in Montenegro may be affected by climate change. Second, in Section 5.3, it describes the methods available for estimating the economic value of future climate change damages in these sectors. Third, in Section 5.4, it evaluates the current capacity that exists in Montenegro to estimate the economic value of climate change damages using state-of-the art models and methods. Fourth, in Section 5.5 it provides very preliminary estimates of the economic value of some of the climate change damages that can be calculated, now, given the information available to this study. Finally in Section 5.6, it suggests how the analytical capacity to improve on these estimates and the institutional capacity to use this information to make public and private sector policy can be further developed.

5.2. Potential Impacts of Climate Change on the Water Resources Sector

The impacts of climate change on water resources are very diverse and cut across many sectors of an economy. This is because water is associated with so many different goods and services that are provided by natural and man-made systems. These include: water for consumption by humans, agriculture and industry, water for non-consumptive uses, such as waste-water treatment, thermal cooling, hydro-electric generation, transportation and recreation and a host of water related services provided by natural ecosystems, such as habitat and species preservation (including disease vectors) and flood control. Despite this diversity, almost (but not quite) all the impacts of climate change on water resources involve some combination of impacts on water supply and/or water use and these, in turn, can result in secondary impacts as when reductions in runoff result in higher pollutant concentrations in rivers and lakes. The major exception is in the area of water temperatures, which are expected to increase with climate change, leading to degraded water quality and fresh water habitats for existing, plants, organisms, and species (IPCC 2001 and 2007)

Table 5.1 highlights in a fairly simple way, the major impacts of CO_2-induced climate change on water resources supply and use, as well the secondary impacts resulting from these two sources (IPCC 2001 and 2007).

According to the IPCC Fourth Assessment Report (2007), there is a great deal of uncertainty about the impacts of climate change on water resources. It is much easier to make statements about the global effects of climate change on crop yields, for example, than it is for water resources. This is partly because the factors that influence surface water and groundwater hydrology vary widely from watershed to watershed and partly because GCM results are often not very accurate at the fine scale needed to simulate the hydrologic cycle in individual catchments (Covey et al. 2003). This is particularly true of the precipitation fields in GCMs (Prudhomme 2006). Furthermore, the resolution of GCMs is not fine enough for them to simulate the processes that give rise to extreme events.

Source of Impact	Type of Impact
Precipitation and temperature-induced changes in quantity, type and distribution of surface water runoff : • decreases in runoff can adversely affect water supply, competition for water and water quality • increases in runoff can increase water supply and water quality and reduce competition for water	Impacts on surface water supply and competition between uses for: 1. Consumptive use • Irrigation • Urban/municipal and industrial water use 2. Non-consumptive use • Hydro-electric generation • Thermal cooling • Transportation • Recreation and tourism • Aquatic ecosystems/habitats Impacts on ambient water quality for: • Waste treatment costs • Aquatic ecosystems/habitats
Temperature-induced changes in water use: • decreases in water use can benefit net water supply, competition for water and water quality • increases in water use can reduce net water supply, increase competition for water and reduce water quality	Impacts on water use by sector: • Irrigation • Urban/municipal and industrial water use in some sub-sectors • Electricity demand • Recreation and tourism
Precipitation-induced changes in groundwater recharge: • increases in recharge increase average annual yields and ground water levels • decreases reduce both	Impacts on groundwater systems: • Average annual yields of rechargeable systems and/or pumping costs for water supply • Ground water table levels and drainage needs
Temperature and precipitation-induced changes in frequency and intensity of peak runoff due to snowpack/snowmelt and storms: • increases in peak runoff increase flooding, erosion and sediment transport, and adverse health impacts • decreases reduce all of the above	Flooding/storm impacts on: • River and lake flooding of urban, suburban and rural land • Urban and suburban flooding due to inadequate drainage • Erosion and sediment transport • Rural and suburban drainage Health impacts on: • Drinking water safety • Waterborne disease vectors
Temperature-induced increases in surface water temperatures: • Increases in temperatures and water temperatures reduce habitat quality and productivity and can degrade ecosystems • Decreases have the opposite effects	Impacts on: • habitat quality • eco-system productivity • distribution of ecosystems

Table 5.1. Summary of Potential Impacts of Climate Change on Water Resources

These two problems make it necessary to downscale GCM precipitation to the regional scale using regional climate models (RCMs) and then to use these data as inputs to hydrologic models that can simulate runoff on a catchment by catchment basis. (Prudhomme and Davis 2007). But even this does not end the problem, since different ways of creating climate scenarios in the RCMs from the GCM climate data results can produce substantial differences in simulated runoff, for example by changing the variability and intensity of precipitation, while holding the average annual values constant. Flooding is an even more complicated phenomenon to simulate at fine geographic and temporal scales, even with RCMs, and in these cases the use of event-based weather simulators to simulate storm behavior introduces further uncertainty into simulations of the effects of climate change on water resources.

Thus the "robust" conclusions that are drawn in the most recent IPCC assessment report about the impacts of climate change on water resources from simulations of hydrologic models using RCM data are somewhat limited:

- Semi arid regions will be the most vulnerable regions to climate change as far as water resources are concerned due to reduced runoff and groundwater discharge. It is not surprising, then, that the southern parts of Montenegro will be the most vulnerable to climate change as shown in the country's first national communication (MSPEP, 2010)
- Where runoff is highly dependant on snow pack and snow melt, warming tends to change the seasonality of flows as a result of reduced snowfall, increased winter rain and earlier snowmelt. This generally reduces the inter-seasonal variability in runoff, which can be a good or a bad thing depending on the type and extent of water storage capacity in a watershed and the temporal distribution of water demand. In Montenegro, mountain watersheds will experience more rainfall and less snowfall. Snow-lines will be at higher elevations. Runoff patterns will be affected, as precipitation is not stored, but runs off into rivers and groundwater more quickly than snow pack, which melts slowly over time. In smaller reservoirs and small scale hydroelectric facilities, changes in the timing of runoff could affect the ability to meet electricity demands.
- Water quality will decrease and sediment transport will increase due to reductions in runoff and warmer water temperatures. The water quality impacts will be most pronounced in dry areas, when flows are low and may not be adequate to treat waste without resorting to secondary and tertiary treatment, which is expensive.
- Climate change will affect the performance and operation of existing and planned man-made hydrologic systems. For maximum benefit, adequate storage and runoff must be available when electricity demands are at their highest point. Climate change can disrupt this.
- A warmer climate will increase the probability of droughts globally and these probabilities will increase as one moves from the equator, pole-ward.
- The local hydrologic cycle will intensify in most places, increasing the likelihood of more intense rainfall and, therefore, increased peak flows (flooding).

Almost all of these conclusions are very general, drawn from local-scale studies of the impacts of climate change in specific catchment areas and, in some cases, large river basins using hydrologic models to translate downscaled GCM climate results into local-scale runoff. The fact that it is so hard to generalize these impacts to the local scale without detailed simulation is important from the standpoint of the models, methods and data required to simulate climate change impacts on water resources.

5.3. Approaches and Methods for Valuing the Physical Impacts of Climate Change

While valuation of climate change damages is a fairly recent field in agriculture it is well-establish. This is not true for the water resources sector. There are very few studies that place an economic value on climate change damages and these are limited in both their geographic scope to some large river basins in the US (Vaux and Howitt 1984; Hurd et al. 1999 and 2004; Hurd and Coonrood) the Berg River Basin in the Western Cape of South Africa (Callaway et al. 2008, 2009) and the Gambia in Africa (Njie et al. 2008). There is no discussion of these studies in the IPCC's Fourth Assessment Report (IPCC 2007). As a result, the discussion, here, is based largely on the small number of existing valuation studies and a more speculative discussion of the application of different methodological approaches to the valuation of a broader scope of impacts.

5.3.1. Hydro-Economic Models

Most of the existing studies cited above use a "hydro-economic" modeling approach to capture both the physical and economic impacts of climate change in large and small river basins. This type of model was first developed for estimating climate change damages by Vaux and Howitt (1984) for large water resource regions in California. It has been successfully implemented for climate change and other applications by Booker (1990) and Booker and Young (1991, 1994) for the Colorado River Basin, by Hurd et al. (1999 and 2004) for the Missouri, Delaware and Apalachicola-Flint-Chattahoochee River basins in the US, and by Hurd et al. (2008) for the Rio Grande River Basin in the American Southwest. More recently, this approach was applied by Callaway et al. (2008, 2009) to the Berg River basin in South Africa to estimate both climate change damages and the benefits and costs of specific adaptation measures to avoid these damages.

These models simulate not only the spatially distributed flow of runoff in a basin to reservoirs and points of water use, but also the dynamic operation of reservoirs, the optimal allocation of water to consumptive and non-consumptive uses, and long-term investment in infrastructure based on a mix of objectives. Most hydro-economic models assume welfare maximizing objectives on the part of water users, super-imposed on traditional safety-first criteria of water planners and the existing allocation procedures in the basin used by water managers.

A graphic representation of a generic model is presented in Figure 5.1. The schematic shows three external sources of information that drive hydro-economic models:

- ***A Regional Climate Model***: This model downscales GCM information about total precipitation and average daily temperature, by month usually, over a long time period (30-50 years) for specific weather stations and runoff gages used in a basin for climate variability/change scenarios.
- ***A Regional Hydrologic Model***: This model converts the spatially-differentiated monthly temperature and precipitation data for the planning horizon in the model from the regional climate model into: 1) Monthly runoff at different runoff gages, 2) monthly reservoir evaporation coefficients for each storage dam, and 3) temperature-driven monthly adjustment factors to change agricultural and urban water demands.

Inputs about Policies, Plans and Technologies: This represents the source of information that can be used to alter various parameters in the dynamic programming core model to reflect alternative demand- and supply-side policies, plans and technologies.

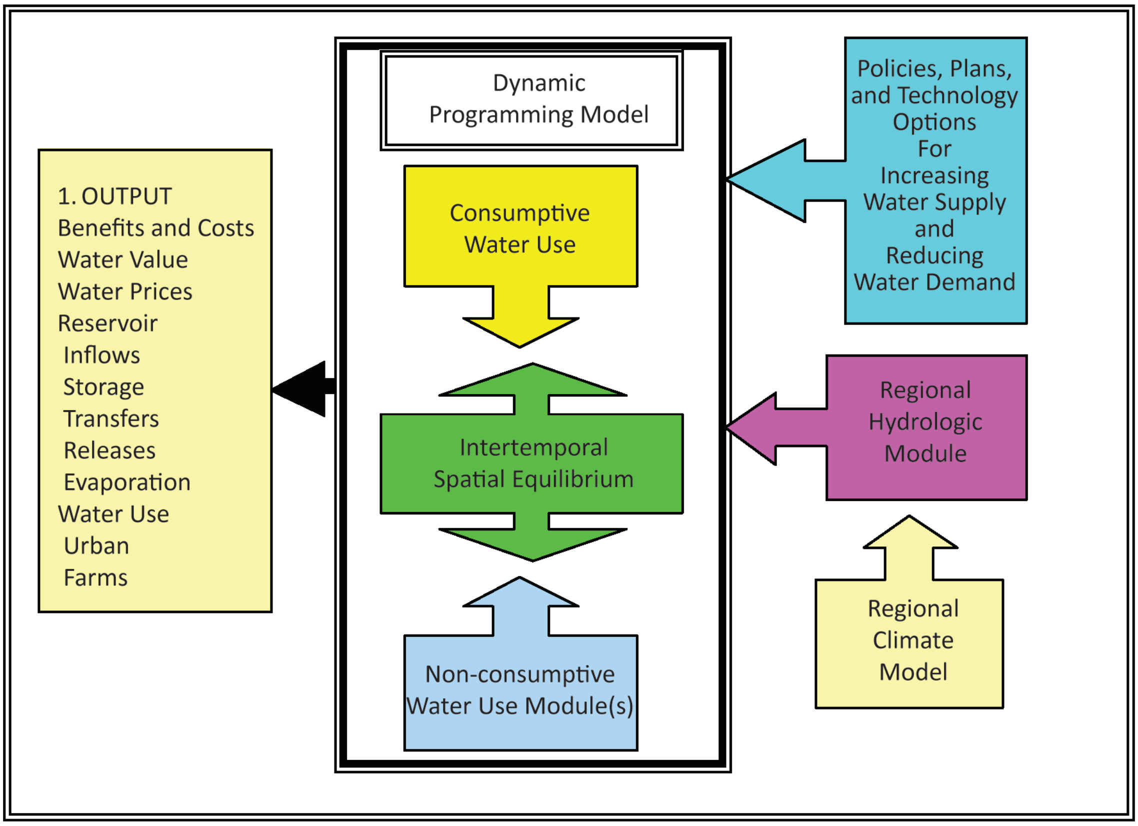


Figure 5.1 Schematic Diagram of a Generic Hydro-Economic Model Used to Simulate the Economic Impacts of Climate Change on Large and Small River Basins

The core of a hydro-economic model is generally a dynamic, non-linear programming (optimization) model. It contains three interlinked modules, as follows. Two of the modules represent either the explicit processes associated with or top-down representations of, consumptive and non-consumptive water uses included in the model, as relevant to the basin. In all of the hydro-economic models, irrigation water demand is determined either by explicit demand curves for water or by demand curves that are derived from process models of a particular sector or set of water-using activities. For example, in the studies by Callaway et al. (2008, 200) the demand for irrigation water was derived from a series of seven farm-level optimization models that were nested in the consumptive water use module, while municipal and industrial water use in Cape Town were represented by explicit downward sloping demand curves. In many applications, non-consumptive water use is modeled using a so called “damage function” approach. For example, in Hurd et al. (1999) several of the basin models included a damage function for water born transportation in which the loss of net revenue by shippers was a function of runoff, which is a proxy for channel depth, in specific river reaches. The water demand and damage functions in these modules, serve as the basis for determining the net returns to water in the objective function of the model (see below).

These water use/damage functions are linked in all these hydro-economic models to an inter-temporal spatial equilibrium module. This module is composed of three parts. It contains:

- *The objective function for the mode* – to maximize the net present value of the economic returns to water in the basin less the costs of operating the system and the costs of investing optimally in infrastructure, such as water supply storage.
- *Spatial constraints* – that link the flow of water between exogenous runoff nodes, water storage reservoirs and points of use in a way that is physically accurate for the basin.

- *Dynamic constraints* – that maintain the intertemporal balances between water storage, runoff and transfers of water into, and releases from, each storage reservoir that is included in the model.
- *System and policy constraints* – that determine the upper and lower physical limits on both water flows and water storage in the system, as well as constraints on water transfers and water use to characterize the existing and alternative rules for operating the system and allocating water on a short- and long-term basis.
- *Reliability constraints* – that set lower limits on water consumption by different end use categories to reflect "safety-first" criteria traditionally used in planning reservoir storage capacity.

Simulating climate change damages is accomplished in four steps, as follows. First, the GCM climate output data (precipitation and temperature) for a given time period is downscaled to the basin and sub-basin level for the relevant time step, usually monthly. Second, a previously calibrated hydrologic model for each basin, sub-basin or catchment area in the model is run to create a new output dataset representing runoff at each exogenous runoff node in the model for each climate scenario. Third, the dynamic spatial equilibrium is run to generate information about the value of the net returns to water by the various water using sectors in the model (including the damage costs for some sectors) for each climate scenario. Finally, the value of the net returns to water in the objective function can be compared for each of the climate change scenarios with the base case value to determine the economic value of the climate change damages. In addition to information about the climate change damages associated with each climate scenario, hydro-economic models can also generate a lot of other information (See Figure 5.1) about the physical impacts of climate change, including impacts on: water consumption and implicit water prices, runoff, reservoir storage and operation, investment in storage capacity and other infrastructure, to name a few.

5.3.2. Hydro-Economic Model Data Needs

Hydro-economic models have three different types of date needs:
- To downscale climate variables to the regional scale
- To calibrate hydrologic models to catchments in the model
- To build the dynamic programming model
- To simulate the physical impacts of climate change and estimate climate change damages

The first two steps do not involve economic modeling and only the broad data needs are considered here. How one downscales, either statistically taking advantage of the correlations and covariances in climate data between weather stations or using a more-physically based climate model or possibly a hybrid of the two, is often determined by what tools are at hand in a given region. In either case, estimating the parameters of a statistical model or calibrating a physically based model, one must have reasonably long records of de-trended, homogenous time series data on relevant meteorological variables. Furthermore one needs to divide these data sets into two different parts: one to estimate the parameters of a statistical model or to calibrate the parameters of a physically based model and another to compare simulated with observed data. Physically based models impose the additional burden of having to use geophysical data sets to represent important features of the local landscape and vegetation that influence local climate processes, such as type of terrain and land cover. Calibrating hydrologic models to produce accurate results requires additional calibration and testing data sets for the model outputs, such as runoff, and meteorological inputs. Simple, water balance models require only limited additional data to take into account the variation in runoff induced by local geophysical features, while spatially distributed parameter models are much more demanding to calibrate and test.

Building the dynamic programming model part of a hydro-economic model is a demanding task, no different than building a spatial equilibrium model of an agriculture sector, as discussed in the previous chapter. To correctly account for water use by different sectors in the basin requires either the data to represent the physical processes and costs associated with water use by a specific sector, using a bottom-up approach, or the data needed to estimate the price-sensitive demand for water by a specific sector, using a top down approach. One must also have enough information about the existing natural and man-made hydrologic systems in the basin to correctly link runoff at many different points to reservoirs to points of end use, taking into account all of the possibilities for operationally moving water around in the basin. In addition one must have information on maximum and minimum flows that can take place at various points in the system due to physical constraints in both natural and man-made systems as well as information about storage capacities for all reservoirs. Finally one must know how water is allocated in the basin and how this imposes constraints on the flow of water and physical withdrawals of water by individual users.

Finally to simulate the physical impacts of climate and estimate climate change damages one requires the output data sets on precipitation and temperature for one or more climate scenario to begin the simulation process using a regional downscaling methodology or climate model. One also needs data to reflect the socio-economic factors at the local level that partially determine water use by shifting the water demand functions in an appropriate fashion within the various water using sectors, as well as data regarding existing or proposed water policies that might influence how water is allocated in the basin.

Given these data needs and the resources needed to acquire the data and develop the model, it is not surprising that the community of hydro-economic practitioners is quite small (but growing rapidly) and the number of studies is small. On the other hand, the success that US and European universities have had in developing the capacity of graduate students to build agricultural sector models of the same general model class, suggests that, while a little daunting, training economists to build and implement hydro-economic models is certainly possible. The main issue has to do with the acceptance of economic models in general by water resource practitioners.

5.3.3. Modeling Other Sectors in Hydro-Economic Models

The most attractive feature about using hydro-economic models to assess climate change damages is that these models ca be used to capture a fairly large number – although not all – of the impacts of climate change on water resources. Existing hydro economic model studies have been able to assess climate change damages associated with water use for irrigation and to avoid salinity damages, municipal and industrial purposes, for thermal cooling and hydro-electric generation, water-born transportation, water-based recreation, waste water treatment, and seasonal, but not event-based, flooding.

The major limitation of hydro-economic models is that by doing so much, they do too little because they invariably take short-cuts, short-cuts that are related to having too large a time step (monthly), not fine enough spatial resolution, or not enough process-detail to accurately characterize hydrologic processes, relevant features of the built environment and human behavior. Therefore, we discuss some alternative approaches that can be used to obtain better and/or different results in different impact categories and sectors.

Flooding

Hydro-economic models can capture regional flooding based on early snowmelt due to consistently warmer-than-average late-winter and early-spring snow melt, using a monthly time step. Accordingly, locationally-specific damage functions relating economic losses to runoff, based on ex post estimates of flood damages, can be inserted into the objective function to reflect flood losses (Hurd et al. 1999). An advantageous feature of modeling regional flooding in a hydro-economic framework is that the model will simulate optimal reservoir operation that is consistent with the multiple objectives of water supply and flood control, as well as any other mix of objectives that are reflected in the water uses included in the model.

However, a monthly time step is far too short to capture event (storm) based flooding that is a serious hazard in many parts of the world. To do this requires the use of a single-purpose flooding model that can simulate hourly runoff peaks, the physical consequences of these peaks to managed and unmanaged ecosystems and the built-environment and then translate these damage consequences in to damage values. One such model, LISFLOOD (deRoo et al. 2000) is currently being used to assess the climate change damages due to flooding in several basins in the EU (Feyen et al. 2006, 2007). The model simulates the spatial and temporal patterns of catchment responses to hourly precipitation in large river basins as a function of topography, soils and land cover and land use. The model computes runoff at a fine scale and routes it according to the physical characteristics of river channels and their flood plains. This information is converted into flooded areas and water depths in the inundated areas. Estimates of flood damages are simulated in the model by applying detailed area data about land and infrastructure values in the flood plane at different water levels in each flooded area to the water depth information using water-depth damage functions. These damages are summed over all flooded areas to provide an estimate of flood damages.

Models like LISFLOOD can be used to estimate flooding of almost any kind due to climatic variability. The key to using them for climate change assessments is to convert the precipitation fields from GCMs and RCMs into the temporal and, sometimes, the spatial resolution required to simulate event-based flooding. This can be accomplished by using "weather generators" that translate climate data into hourly weather based on observed relationships between climate and weather at existing weather stations. These models also require a great deal of information about land use at a cross-sectional level both for flood routing purposes and estimating economic damages as a function of water elevation. The economic information required to develop these damage functions is also quite large due to the fine spatial scale resolution in the model.

Water-based Recreation Demand and Tourism

Water recreation has been included in hydro-economic models (Hurd et al. 1999) in the form of damage functions that relate runoff and lake water levels to welfare from related studies in a basin. A more complete discussion of estimating the economic impacts of climate change on recreation was included in Chapter 4. However, we can quickly summarize the main approach that can be used to estimate climate change damages on water-based recreation in micro-economic studies.

The travel cost approach, introduced in Chapter 4, has been used extensively to estimate how changes in the environment affect not only the trips they take to recreation sites, but also their welfare. In the case of fresh-water based recreation, river discharge rates and lake levels can be important determinants of recreation demand. (Cameron et al. 1996). Both of these are based primarily on runoff and to a lesser extent surface water evaporation and plant-soil evapotranspiration, all of which are related to precipitation and/or temperature. Drawing all this together means that, given the right data set we should be able to estimate the parameters of a regression model that explains the variation in a measure of recreation demand (trips, recreation days, or overnights, etc.) as a function of the relevant climate variables, travel costs from zones of origin to recreation destinations, and various control variables to reflect other site characteristics and the characteristics of recreators.

Using this type of approach Mendelsohn and Markowski (1999) were able to simulate the changes in recreation demand and welfare (willingness-to-pay) due to parametric changes in temperature and precipitation for seven different recreation categories in the US. In a slightly different vein, Cameron et al. (1996) estimated the changes in recreation participation and welfare due to changes in discharge rates and water levels at a number of recreation sites on the Columbia River in the US and Canada. While the hydrologic changes were not due to climate, but to changes in system operation, the approach remains valid. An interesting difference between the two studies is that, whereas Mendelsohn and Markowski used information about observed recreation demand, Cameron et al. asked people how they would change the distribution of their trips to different sites in the face of changes in river discharges and lake levels, as depicted in simulated photographs of the recreation sites.

Waste Water Treatment

Much of the waste water treatment in both developed and developing countries relies primarily or partially on the use of water to dilute pollution from many different sources, through primary or secondary treatment. However as waste loads increase or river discharges decrease, municipalities will either have to face an increase in water pollution or move to tertiary treatment and disinfection to attain a given set of water quality standards at substantially higher costs (Hurd et al. 1999). Thus, a climate-induced reduction in runoff could either lead to a reduction in the benefits of clean water as estimated in a number of studies (Smith and Desvouges 1983, 1985 and 1986) or to higher waste treatment costs in order to achieve existing standards.

Hurd et al. (1999) “transferred” estimates of the benefits of secondary waste treatment on the Missouri River to construct a functional relationship between water quality benefits and runoff at different reaches in the river and modeled the costs of additional tertiary treatment as a function of the reduction in runoff below a threshold where tertiary treatment would be required, holding water quality (BOD) standards constant.

To repeat the analysis would require determining how relevant water quality parameters are affected by runoff and linking runoff to climate change for major cities using river water for waste treatment. To conduct an analysis of the benefits of improved water quality would require additional work in the form of local microeconomic studies to estimate the benefits of clean surface water at various locations. Such an analysis could be performed using either a characteristics-based travel cost model approach in which water pollution parameters represent site characteristics or by asking people directly what their willingness-to-pay for improved water quality is at different sites. Both approaches are data intensive and time consuming, requiring large samples of respondents, very detailed surveys and sophisticated survey designs and the use of fairly sophisticated statistical and economic analysis techniques to estimate model parameters and simulate the climate change impacts. Constructing estimates of the additional cost of tertiary treatment due to reduced runoff would, in turn, require developing estimates of the threshold runoff levels where tertiary treatment would have to be implemented to maintain existing water quality standards and estimates of the investment, operation and maintenance cost of tertiary treatment facilities and activities for different cities.

Hydroelectric Power Generation

While hydroelectric water use has been included in some hydro-economic models (Hurd, 1999), the representation has been partial, limited only to specific river basins. It has not taken into account the interactions between the hydroelectric system and all of the other sources of electricity supply on the grid, as well as the demand for electricity. To do a full study of the impacts of climate change on the hydroelectric system requires looking at the system as a whole, starting with individual plant.

How much electricity can be generated from a given reservoir depends on the operating characteristics of the hydroelectric generating plant, how much water can be released from the reservoir to propel the turbine, and how much pressure this water has behind it. Given the instantaneous generating capacity of the hydro plant only the last two factors really matter in determining how much electricity can be generated instantaneously up to that maximum capacity. Both of these variables are essentially a function of how much water is stored in the reservoir, given the relationship between storage and the water level of the reservoir, through its stage-area curve. Run-of-river reservoirs have even fewer variables to worry about. Lacking storage to supply them, electricity generation is dependant only on instantaneous discharge volumes.

In both types of plants, reductions in runoff will reduce the amount of electricity that can be generated. However, where the water to turn the turbine blades is supplied by a reservoir, the reservoir will act as a filter and the effect of a reduction in runoff may either be delayed to a later time period or spread over many future time periods. In that case, the timing of electricity demand becomes important and this factor requires us to take into account how well the rest of the generating system can respond to instantaneous electricity demand, given a reduction in runoff that might create a temporary hole in the electricity supply profile. Thus, to correctly analyze the effects of climate change on hydro-electric generation one has to take a much broader system perspective that involves the entire supply profile and how electricity is dispatched to meet short-run variations in demand. In the long-run perspective, one needs to look at the effects of climate change on investment in non-hydro generating capacity that might have to replace some part of the lost hydro generating capacity. And, in all of these cases, one needs to take into account that some electricity demands will also be affected by climate change through seasonal temperature shifts, affecting both system capacity and the mix of generation required to meet base load and peaking needs.

Finally, the value of the climate change damages of short-run losses in hydro generation due to climate change have to take into account the additional cost of dispatching electricity from a higher cost generating source to meet an instantaneous demand. In the somewhat longer term, the estimate of climate change damages needs to take into account that one option of the utility is to increase electricity prices, thereby causing a loss in consumer surplus. In the very long run, where everything is variable additional investment costs and their impact on energy system costs and prices must also be calculated in order to determine how both electricity producers and consumers are affected by climate change.

Groundwater

Of all the areas involved in assessing the impacts of climate change on water resources, the one we know the least about is groundwater. This has not changed greatly during the interval between the third and fourth assessment reports (IPCC 2001, 2007). The major difficulty is the lack of systematic area mapping and modeling of groundwater systems. Not surprisingly, existing groundwater resources have either been ignored in hydro-economic modeling or else the selected locations have not had significant ground water resources to worry about. A major exception to this is ongoing work by McCarl and various colleagues (2001 and 2005) on the Edwards aquifer in Texas. This work is based on a spatial equilibrium model (Williams, McCarl and Chen 2006) of the regional agricultural and urban water demand sectors. The part of the model that determines the demand for water is connected to a 3-dimensional model of a karst aquifer that is, in turn, coupled to an exogenous regional climate model that determines how much precipitation is available to recharge the aquifer at specific recharge points. For any given climate scenario, the model can simulate how the water use sectors and the aquifer will interact and the impacts on net returns to water among the users of this aquifer.

5.4. Current Capacity to Estimate Climate Change Damages in Montenegro

The capacity to simulate the impacts of changes in temperature and precipitation on changes in runoff in river basins exists in Montenegro, but appears to be very rudimentary. Water balance or more sophisticated rainfall-runoff models are required to simulate the effects of changes in temperature and precipitation on runoff, reservoir evaporation and potential evapotranspiration by plants in a hydro-economic basin model. Based on the information in the First National Communication, it appears that the current capacity to simulate climate-related impacts on runoff is limited to statistical methods used to correlate observed runoff with observed precipitation, only. We found no evidence of a rainfall runoff model (or study using such a model) that had been calibrated to a specific basin in the country and then used to simulate the impacts of climate change on water balances in various parts of the basin.

Hydro-economic models don't exist for basins in Montenegro. But this is not surprising since the expertise to build such models resides in a small number of developed countries and is a relatively new, but growing field. Besides, it is not really clear that Montenegro needs such an advanced type of model to help plan its water resources development for quite some time. What it does need is the capacity to develop hydro-economic models that can help guide existing development. This means models that be used to plan future hydro-electric facilities and optimize their size to climate variability and climate change in an economic framework. Traditionally, climate and water demand risk have been addressed by increasing the storage capacity of dams in order to increase their reliability. This is done using historical runoff data as a guide to future runoff to ensure that the dam can be filled by existing runoff. However, in the future climate change will change runoff patterns in ways that are hard to predict. This increases the possibility, discussed earlier in this study, that planners will make their hydro facility either too big or small in terms of the ability to fill and operate the dam effectively at its designed capacity. This new form of risk limits the old strategy of reducing risk by increasing the size of the dam. To deal with this, not only requires the capability to factor climate change into future runoff projections, but also different methods for dealing with risk, such as reducing the "regrets" of planning for one climate scenario that may not actually occur in the future (Matalas and Fiering 1977).

5.5. Preliminary Estimate of Climate Change on Hydroelectricity Generation, the Piva River

Given the current and future importance of hydroelectric generation to Montenegro's economy and water resources situation, it was decided to try to make a preliminary estimate of the effects of climate change on the gross revenues from the production of electricity at the Piva River power plant. The Piva River was dammed in 1975 to form a large lake, which is the third largest in the two countries of Montenegro and Serbia. The surface area reservoir at maximum capacity is 112.5 km^2 and it is 188 m deep at its deepest point. The maximum storage capacity of the reservoir is about 790-800 million m^3. The hydroelectric facility, located at the Mratinje Dam has an installed capacity of 342 MW and is capable of delivering up to a maximum of 860 MWh of electricity on an annual basis.

A comprehensive estimate of climate change damages for a particular generating plant or group of generating plants would require the following steps.

- Simulating the effects of climate change on runoff into the reservoir and surface water evaporation, using a regional climate model in conjunction with a rainfall runoff model for the affected basins.
- Simulating the effects of climate change on the domestic and export demand for electricity.
- Using a reservoir management model (hydro-economic model) to simulate monthly reservoir operation over time for each reservoir, balancing water availability to generate electricity with electricity demand.
- In the process, the hydro-economic model would produce estimates of the effects of climate change on the annual gross and net income, by year, for each power plant and the associated net present values of these income flows over time. The model would also calculate the impact on the economic well-being of consumers due to higher electricity prices.

Since all the models and all of the necessary data to do this have not been developed, the approach used here to calculate climate change damages was based on much more limited information. The methodology was as follows. First, a statistical relationship was developed between monthly water releases from the reservoir and the amount of electricity generated. Unless the dam is also operated for other objectives that create large conflicts with power generation, there should be a close relationship between these two variables at the monthly (but not necessarily the annual) level. This is simply because either most of the water released from the reservoir (except for spills) will pass through the turbines to generate electricity. Even if this is not the case, the pattern of month-to-month fluctuation should be very close. To test this, simple linear statistical (i.e., regression) models were developed to explain the monthly variation between power generation, and monthly water releases, monthly runoff, and monthly storage (one at a time), using observed data for the period 1984-2009, provided by the operators of the power plant..

Figure 5.2 illustrates the association between monthly power generation (on the vertical axis and monthly releases on the horizontal axis). The relationship is quite linear as illustrated by the regression line that passes through the data[27]. Furthermore the linear model used to fit this line to the data explains around 88 percent of the variation between monthly power generation and releases.

27 The regression line is plotted using the linear equation shown inside the chart: Monthly Generation (y) = 3531.8 + 1027.8 * Monthly Water Releases (x).

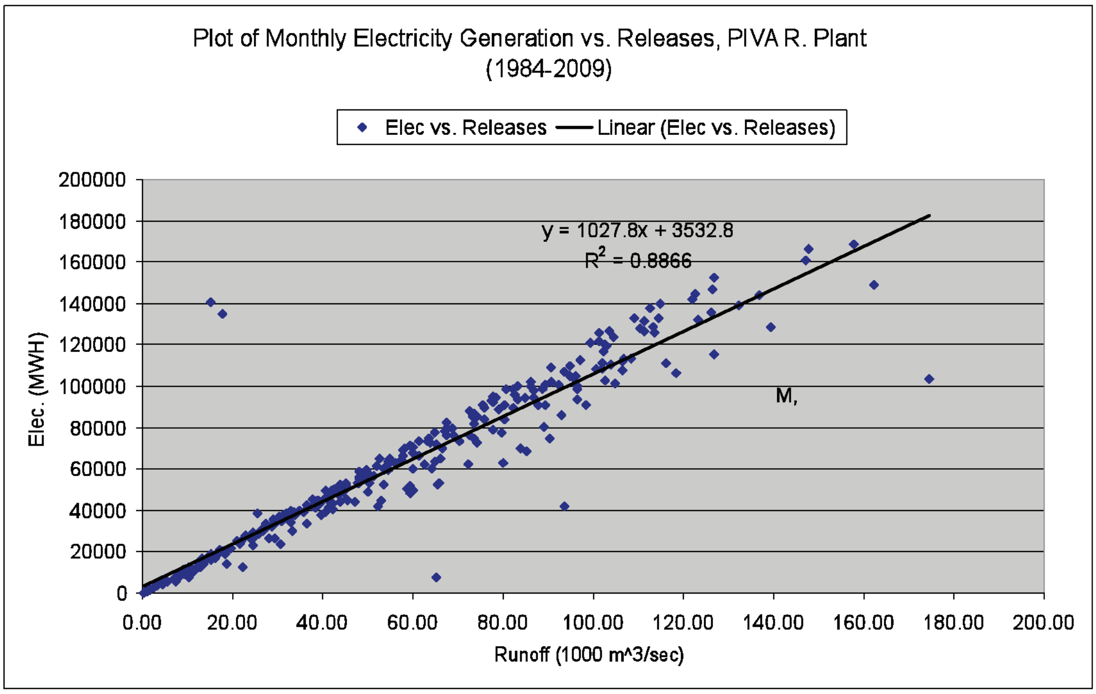


Figure 5.2 Plot of Monthly Electricity Generation at Different Monthly Release Rate for the Mratinje Dam on the Piva R. (1984-2009)

The estimates of the change in electricity generation due to reductions in runoff were based on the assumption that, to generate electricity, at least as much (probably more) runoff had to flow into the reservoir at one time or another to be passed through the turbines (as releases). This is a safe assumption, since reservoir evaporative and seepage losses will always ensure that total releases are less than total runoff, after accounting for storage differences in the reservoir. However, accounting for these storage differences over time is important as the amount of power that can be delivered over a period as long as a month will depend on the distance between the surface of the reservoir and the turbine blades, which is basically a function of reservoir storage. Storage differences also matter in the relationship between runoff and releases because, depending on the relationship between storage capacity and the timing and magnitude of both runoff and releases, the storage period for any particular flow into the reservoir may not correspond with the timing of the release. Therefore to correctly estimate the effects of reduced runoff on power generation one needs to use a reservoir model that at least balances the difference between beginning and ending reservoir storage (for any given period) with runoff (inflows), evaporation and releases.

Lacking the time and resources to implement such a model, a short-cut was taken, namely: it was assumed that monthly runoff had to balance monthly releases, less evaporation[28]. Given that assumption, the impacts of climate change on runoff were simulated by reducing observed monthly runoff for the period 1976-2009 (which represented the Base Case) by the percentages shown in Table 5.2. These monthly reductions were used to calculate the average monthly, annual, and average annual runoff due to climate change for the two climate scenarios. All of the runoff and power generation data were supplied by the operators of the dam. Next, the linear regression equation represented in Figure 5.2 was applied to the monthly runoff data for the Base Case and the two climate scenarios to simulate

28 The assumption that annual runoff had to balance annual releases, less evaporation was also tested and the results were not much different. The reason that the assumption about monthly balance was maintained was that it made it possible to vary runoff on a monthly basis using the A1B NF and A1B FF climate change scenarios.

power generation in the Base Case and the effects of climate change on monthly power generation in the climate scenarios (assuming that monthly releases could not be any larger than monthly runoff). Finally, the changes in projected power generation from the Base Case were calculated for each climate change scenario. These simulated changes in electricity production due to climate change were then valued in economic terms using a price of 82 €/MWh[29].

Table 5.2 Percent Reduction in Monthly Average Runoff Assumed in Economic Analysis for Two Climate Scenarios and Base Case

Climate Change Scenario	Percent Reduction in Runoff by Period			
	Dec. – Feb.	Mar. – May	June – Aug.	Sep. – Nov.
Base Case	0 %	0 %	0 %	0%
A1B NF	-10 %	-10 %	-5 %	-20 %
A1B FF	- 30 %	-10 %	-15%	- 40%

Source: Based on Information Presented in Montenegro's First Annual Communication to the UNFCCC (MSPEP, 2010).

These results are shown in Table 5.3. In scenario A1B NF average annual electricity generation by the plant falls from about 750 MWh during the Base Case period to about 665 MWh. This creates an average gross revenue loss of about 6.6 million €/year. For the A1B FF case, average annual electricity generation falls even further, to about 590 MWh and the associated loss in gross operating revenues is around 13 million €/year. Keep in mind that that these estimates were made using an electricity price of 82 €/MWh - the price to import substitute electricity. Higher or lower prices would change the estimates of increased costs.

Table 5.3 Runoff, Power Generation and Average Monthly Gross Revenue from Electricity Sales for Power from the Mratinje Dam in the Base Case (1984-2009) and Two Climate Change Scenarios and the Estimated Average Annual Loss in Revenues from the Reduction in Revenues In the Two Climate Change Scenarios

Climate Scenario	Ave. Mo. Runoff (m^3/sec)	Ave. Annual Power Gen. (MWh)	Ave. Mo. Power Gen. (MWh)	Ave. Annual Revenue (million €/ year)	Ave. Mo. Revenue (million €/ year)	Ave. Annual Revenue Loss (million €/ year)
Base Case	57.1	746,196	62,183	61.2	5.1	--
A1B NF	50.5	665,456	55,455	54.6	4.5	-6.6
A1B FF	44.4	590,150	49,179	48.4	4.0	-12.8

29 This price is based on local, expert judgement by members of the National Communication study team using current-day prices for imported electricity.

These estimates apply only to the Mratinje Dam on the Piva River. The economic losses calculated here may be offset by reductions in the cost of operating the plant, but these impacts would probably be small. So, the economic estimates provided here represent legitimate welfare losses and are a measure of the climate change damages to electricity producers. The estimates of economic losses also do not include the loss in welfare by electricity consumers who would probably face higher prices for electricity from alternative sources. Higher electricity prices than they would pay for electricity from the Piva plant, without climate change, will reduce their welfare. However, the additional expenditures on electricity by consumers, if calculated, would not be a valid measure of climate change damages experienced by consumers. What one must calculate is the reduction in willingness-to-pay by consumers due to higher prices, less the difference in their expenditures in electricity[30]. This loss was not calculated because the approach used here did not take into account economic market effects as would be the case if a hydro-economic model had been used. Finally, the water balance approach that underlies this analysis is based on strong assumptions about the timing of runoff into the dam and releases of water from the dam. The use of a hydro-economic model would have simulated the correct reservoir balancing process. It is hard to judge the impact of these methodological limitations on the preliminary estimates of climate change damages in the last column of Table 5.3.

5.6. The Way Forward in the Water Resources Sector

5.6.1. Main Findings

- The capacity to simulate basin and catchment-level runoff using rainfall runoff models does not appear to be well-developed in Montenegro. The data required to support the calibration of these models is unknown.
- The capacity to simulate the impacts of climate change on runoff appears to be based mainly on the use of empirical (i.e., regression) models on an "as needed" basis.
- The capacity to develop and implement basin-level hydro-economic models does not exist, but the needs of the country for such models may be relatively limited, primarily related to the hydroelectric generation.
- Finally, a macroeconomic model for Montenegro to simulate the impacts of climate change in the water resources sector on important indicators of national economic development does not exist, nor does the capacity to develop and implement such a model.

5.6.2. Main Recommendations

- Short-Term (Next Few Years):
    - o Efforts should be made to involve Montenegrin experts with the work of existing centers of expertise in water resources modeling to improve the capacity to calibrate state-of-the art rainfall runoff models
    - o Any existing projects to improve climate and water resources data bases in the country should be coordinated with an eye to supporting calibration and implementation of better rainfall runoff models for use in both development- and climate-related assessments.
    - o On-going or planned pre-feasibility or feasibility studies for hydroelectric projects should be required to include an assessment of the physical and economic impacts of climate change.
    - o The implementation of such assessments should involve the participation of

30 This difference, formally, is the reduction in "consumers' surplus, which is an often used measure of consumer welfare changes due to higher prices, resource scarcity and environmental damage.

Montenegrin hydrologists and water resources planners, at the very least for capacity-building purposes.

- Long-Term (Five – Ten Years)
    - Together with future development planning activities and climate-related assessments, undertake a program: 1.) to identify key basins that are considered vital to Montenegro's future economic development; 2.) calibrate rainfall runoff models to these basins; and 3) use these models in future environmental and economic assessment related to economic development activities and climate change.
    - Undertake to create and enhance the capacity to develop and implement a selected number of basin-level hydro-economic models to assess future water resources development and environmental issues, such as hydro-electric development, waste water treatment and irrigated agriculture.
- Cross-Cutting (Applies to virtually all sectors)
    - Ensure that any macroeconomic model that is developed for Montenegro can assess sectoral data "entry points" that make it possible to use such a model to accurately simulate the national level economic impacts associated with water resources related development and environmental impacts. (Many macroeconomic models limit these "entry points" to sector-level output, only)

6. CLIMATE CHANGE DAMAGES IN THE HUMAN HEALTH SECTOR

6.1. Introduction: Background and Objectives

6.1.1. Background

Traditionally policy discussions about climate change have concentrated on the costs of reducing greenhouse gas emissions by mitigation. However, as the emphasis of these discussion shifts towards the physical impacts of climate change and options for avoiding these impacts through adaptation, interest is also growing for estimating the social costs of climate change and the social benefits of avoiding these impacts by both mitigation and adaptation. In this discussion, the relationship between climate change and human health is beginning to play a larger and larger role.

A number of recent studies have assessed the social cost of climate change, at the local (Baccini et al. 2008), regional (PESETA 2009) and global level (Watkiss et al.2005). Almost all of the studies in the area of human health have focused on temperature-related mortality. This includes mortality due to heat waves and cold waves. High ambient air temperatures are associated with mortality from heat stroke, cardiovascular, renal and respiratory diseases, metabolic disorders, etc. Low ambient air temperatures are associated primarily with cardiovascular disorders (e.g. heart attacks) and with mortality from direct exposure. In that general context, climate change that results in increased peak temperatures and heat waves should increase death rates, while winter warming and more rainfall in place of snowfall should result in reduced cold wave mortality.

The impacts of climate change on cold and heat wave related mortality may be quite large, but these impacts may be reduced substantially by acclimatization as countries experience higher temperatures and people adjust to these changes. For example, the PESETA study, which covered all of the EU countries, estimated that average annual heat wave mortality due to climate change, alone, could increase deaths in the EU as a whole by as much as 150 percent in the period 2011-2040, compared to the Base Case, but that acclimatization could actually reduce the death rate so that it was about 80 percent lower than in the Base Case period. For the period 2071-2100, it was estimated that climate change could increase deaths by as much as 650% compared to the Base Case, but that advanced acclimatization, again, could bring the death rate back down so that it would be about 80 percent lower than in the Base Case. Projected cold wave mortality showed that climate change would reduce deaths, due to fewer heart attacks. For the period 2011-2040 the simulated effect of change resulted in decreased deaths to cold waves by as much as -165% compared to the Base Case. However the effect of acclimatization was less pronounced, leading to death rates that were about -105% lower than in the Base Case period. The pattern was almost the same for the period 2071-2010. Increasing temperatures in the winter due to climate change would reduce deaths in the EU by as much as about -130 percent, while acclimatization would reduce death rates by around 120 percent below the Base Case death rate.

6.1.2. Objectives

Given the recent interest in heat and cold wave mortality, the paucity of data available to look at other potential health effects of climate change, and the relatively short time span available to gather and organize the relevant health data in Montenegro, it was decided to focus this study on heat wave and cold wave mortality. Along these lines, this chapter has five main objectives. First, in Sections 6.2 it summarizes how human health may be influenced by climate change. Second, in Section 6.3, it describes the methods available for estimating heat and cold wave mortality and the economic value of future climate change damages associated with changes in mortality due to climate change. Third, in Section 6.4, it evaluates the current capacity that exists in Montenegro to estimate both these changes in mortality and the economic value of the climate change damages associated with heat and cold wave mortality. Fourth, in Section 6.5 it provides very preliminary estimates of the economic value of some of the climate change damages that can be calculated, now, for heat and cold wave mortality in Montenegro, given the information available to this study. Finally in Section 6.6, it suggests how the analytical capacity to improve on these estimates and the institutional capacity to use this information to make public and private sector policy can be further developed.

6.1.3. Potential Impacts of Climate Change on Human Health

Climate change has a range of complex inter-linkages with health. These include direct impacts, such as temperature-related illness and death, and the health impacts of extreme weather events. It also includes other impacts that follow more indirect pathways such as those that give rise to water- and food-borne diseases; vector-borne diseases; or food and water shortages. It can also include wider effects on health and well-being.

It is also highlighted that good public health depends on safe drinking water, sufficient food, secure shelter, and good social conditions, which may all be affected by a changing climate – and are particularly important in the developing country context. Figure 1 from the World Health Organization (WHO), illustrates some of the ways in which climate impacts upon health. This report does not attempt to quantify all these aspects – instead it focuses on the key primary health impact routes related to temperature.

6.1.4. Temperature

There is a direct relationship between mortality and temperature that differs by climatic zone and geographic area. High ambient temperature is associated with mortality from heat stroke, cardiovascular, renal and respiratory diseases, metabolic disorders, etc. The effect of temperature on mortality is greater for respiratory diseases and cardiovascular diseases than for other causes of death. The most vulnerable are those over the age of 65 years. Reports assessing the health impact of the European heat wave in 2003 demonstrate that the mortality of that event was greatest on the very old: for example, excess mortality in France was estimated at 20% for those aged 45-74 years, at 70% for the 75-94 year age group, and at 120% for people over 94 years (Pirard et al. 2005).

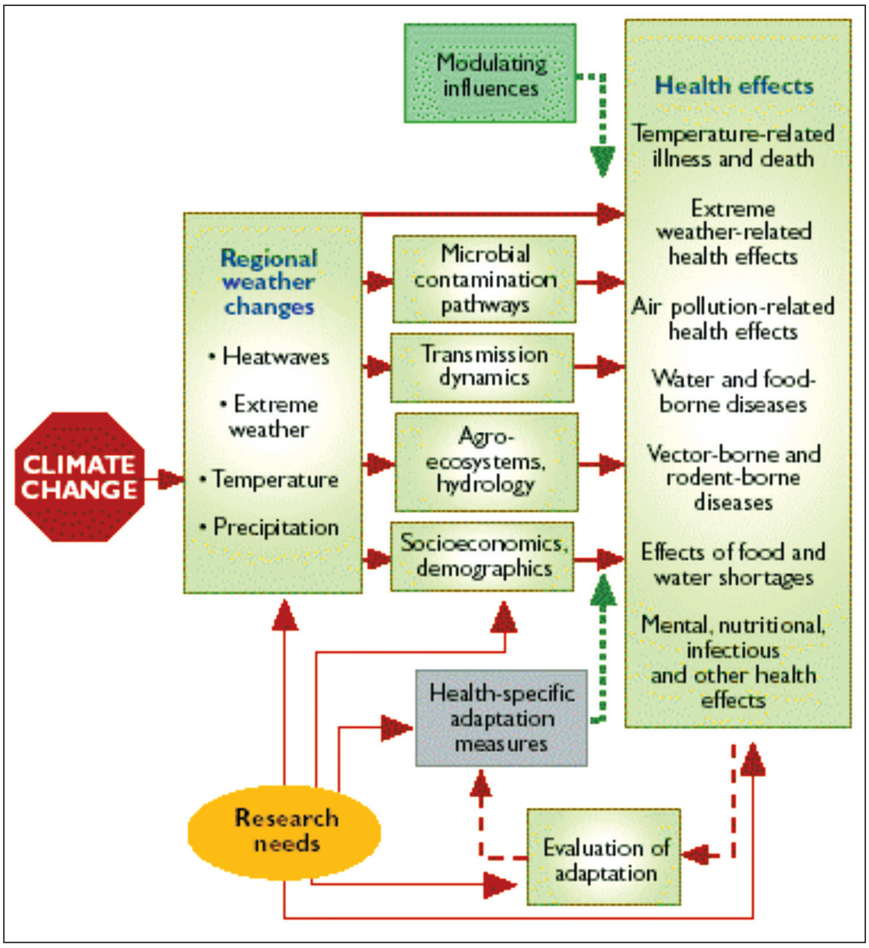


Figure 6.1 Pathways for climate impacts on health (PESETA, 2009)

Climate projections indicate an increase in average temperatures and incidence of heat waves. However, rising temperatures will also reduce winter excess deaths (and at present the cold leads to far more deaths than the heat in Europe). This will have particular benefits in northern latitudes of Europe. By 2080 in Europe, it is likely that cold winters will have almost entirely ceased, except at higher elevations and by that time snow lines will have risen significantly in elevation (EEA 2004).

Comparatively fewer studies have assessed the impact of high or low temperatures on morbidity (such as hospital admissions). There is little published evidence of an association between weather conditions and measures of morbidity such as hospital admissions or primary care consultations. One study of general practitioner consultations among the elderly in Greater London found that temperature affected the rate of consultation for respiratory diseases but not that for cardiovascular diseases.

6.1.5. Food borne disease

Temperature can influence transmission of salmonella infections, and has been estimated to be associated with about 35 % of all cases (including in the Netherlands, England, Poland, Switzerland and Spain) (Kovats et al. 2004). In general, cases of salmonella increase by around 5–10 % for each degree increase in weekly temperatures, above a threshold of around 5 °C. Inappropriate food preparation and storage around the time of consumption appears to be the key factor.

6.1.6. Vector-borne disease

Climate is an important determinant of the geographic range of vectors carrying a range of diseases. There have been increases in incidence of malaria, tick-borne encephalitis, Lyme disease, Leishmaniasis, in Europe over recent decades, however this may or may not be due to recent climate change (e.g. the influence of increased travel, or changes in leisure activity affecting exposure are also important). Many of these vector borne diseases have been shown to have potential high impacts in climate studies at a global level, though predictions in Europe are low.

6.1.7. Extreme events – floods and storms

Floods are the most common natural disaster causing loss of life and economic damage in Europe. Adverse health impacts associated with flooding include direct physical effects (drowning and injuries), but also wider effects on well being (e.g. mental illnesses from the effect of flooding and displacement) and potentially increased risk of food and water borne disease. Between 1975 and 2001, 238 flood events were recorded in Europe. Over this period the annual number of flood events increased. The number of people affected by floods rose significantly, with adverse physical and mental health consequences[31].

6.1.8. Acclimatization

We distinguish in this study between acclimatization (those elements of physiological and behavioral change that take place autonomously and automatically by individuals and within populations) and adaptation (those actions taken specifically in a planned and proactive way to address climate change).

Human beings have the capacity to acclimatize to their surroundings over both the short and long term. This means that extreme high temperatures have a greater impact on human health if they occur early in a summer season rather than late; likewise, extreme cold temperatures have a greater impact if they occur early in a winter season. Over longer timescales, it is also possible for some degree

31 Impacts of Europe's changing climate: An indicator-based assessment EEA Report No 2/2004

of physiological acclimatization to occur. This is seen in populations migrating between climatically dissimilar regions of the world, and is also expected to occur as climate changes through time in one location. Similar effects can also be seen comparing different regions of Europe. Since at least the 20th century, populations in temperate regions have had death rates higher in winter than in summer. The countries with the highest rates of "excess" winter mortality in Europe are Portugal and Spain, while excess winter mortality is lowest in the Scandinavian countries, although their winters are much colder. Scandinavians are well adapted (acclimatized) to cold temperatures, while housing standards in southern and Western Europe may play a strong part in mortality seasonality (e.g. Healy 2003).

Acclimatization to warmer climate regimes is likely to occur in individuals and populations, given the rate of change in mean climate conditions currently projected by climate models (McMichael, et al. 2004). However it is uncertain whether populations are able to adapt to non-linear increases in the frequency or intensity of daily temperature extremes (i.e., heat waves).

Planned and proactive adaptation can reduce climate impacts in different ways. It may reduce population exposure to climatic stimuli (e.g., through urban planning and design); it may reduce population sensitivity (e.g., through vaccination programs); it may modify the non-climate risk factors (e.g., control of disease vectors); or it may reduce the direct impact of the disease (e.g., through early notification and treatment).

Climate change impacts on health and possible adaptation strategies in Europe have been reviewed recently in a project led by the WHO (Europe). This project, known as cCASHh, provided an extremely useful summary of latest research in these areas[32], and we have built upon some of these results. Another current Commission-funded project, PHEWE, has increased the knowledge base on the impacts of climate on health – with a focus on temperature effects. This project has examined reported health statistics alongside meteorological data in 15 cities across Europe, to produce statistical functions relating weather and health endpoints (Baccini et al. 2008).

6.2. Approaches and Data Needs for Valuing the Physical Impacts of Climate Change

6.2.1. Methods for Estimating the Economic Impacts of Temperature-Induced Mortality due to Climate Change

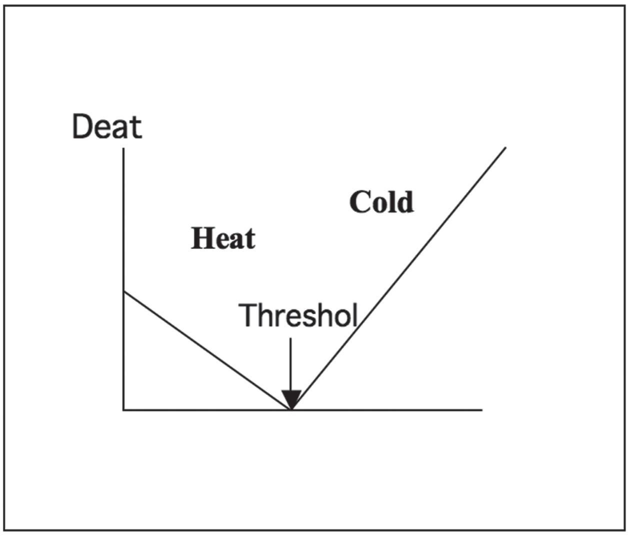
Unlike the Agricultural, Forest, Tourism and to a certain extent the Water Resources sectors, there are no specific models (such as EUFASOM or HTM) in the health sector that characterize all of the environmental-economic relationships required to estimate climate change damages. Nevertheless, virtually all studies of health effects due to climate change follow the same basic methodological steps. The overall method for the health analysis in many recent studies combines current health impact assessment and valuation models (built within databases and Geographical Information Systems) with daily climate data and empirical temperature-health relationships to estimate additional deaths attributable to heat and cold stress.

At the heart of the analysis of heat and cold wave mortality are functions that characterize the relationship between mortality and temperature for heat and cold waves. The shape of the temperature-

32 Menne and Ebi (Eds.), 2006: Climate change and adaptation strategies for human health. WHO (Europe).

mortality association is approximately U-shaped or V-shaped, with mortality increasing at both low and high temperatures. The relationship between daily mortality and the thermal environment is much closer and more short-lived in summer than in winter. Such a function is shown in Figure 6.2. To quantify the effect of temperature on mortality, a linear relationship is assumed above (and below) a threshold temperature(s). To the left of the threshold lies the cold wave mortality part of the function. Temperatures below this threshold value result in cold-related deaths that increase, according to the slope of this part of the function. The steeper it is the greater the number of deaths for a one degree decrease in temperature. To the right of the temperature threshold lies the heat wave part of the function. Temperatures above this threshold result in heat-related deaths. The steeper the slope, the more heat-related deaths occur due to a one degree increase in temperature.

Figure 6.2 Generic Temperature Mortality Function



There are two approaches used in the literature to quantify the temperature-mortality relationship:

- Epidemiological studies on a country-by-country basis deriving absolute functions consisting of thresholds and linear relationships based on statistical analysis of daily (or monthly) temperature and mortality (e.g., cCAHSh, McMichael et al. 2004; Kovats and Jendritzky, 2006, and references therein). Baccini et al. (2008) have developed non-linear heat mortality functions for 15 cities in the EU.
- Similar studies which derive climate-dependent functions, with thresholds based on the average climate in a specified location (such as a particular percentile in the daily mean temperature series for the location), and linear relationships (e.g., Kovats et al. 2006).

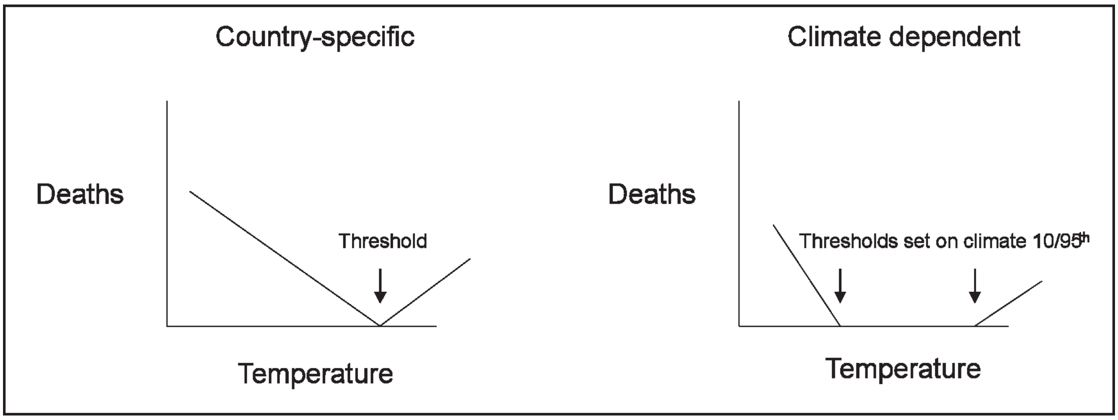
In each case, thresholds tend to vary from country to country, with lower threshold temperatures in the north, and higher threshold temperatures in the south. No such function has been estimated for Montenegro or for any city in the country.

There are also basically two different kinds of temperature mortality function (See Figure 6.3):

- Absolute functions – these have a single threshold value, based on correlations between deaths and temperatures for specific cities or countries, and

- Climate-related functions – these have climate-dependent thresholds for both heat and cold functions, based on a statistical analysis of daily temperatures in each location, resulting in a separate fixed single slope (gradient) for heat and cold related mortality.

Figure 6.3 Schematic illustration of exposure-response functions linking temperature and mortality, following two approaches.



An important feature of heat and cold wave mortality is acclimatization. Early work done on heat waves by Kalkstein et al. (1989) revealed that heat wave mortality was highest in cities that were located in places where summer averages and peaks were furthest apart. This simply means that in places where it is already hot, people are already prepared to deal with a little more heat. The same thing, it turns out, is also true for cold waves. The colder the average winter temperature, the fewer people die due to cold waves. While acclimatization has been observed in many cross-sectional studies, its full dimensions are not known. Specifically, it is hard to identify how much acclimatization is due to what humans do to adapt to heat waves in the short-term and how much is due to longer term adjustments, such as changes in building design and the penetration of air conditioning into residential and commercial buildings.

It seems like that some physiological and behavioral acclimatization to the changing climate will occur, just as it does to climate variability. Few studies have attempted to incorporate acclimatization into future projections of temperature-related mortality, but all studies indicate that acclimatization would reduce potential increases in heat-related mortality. It is therefore incorrect simply to apply the temperature-mortality relationships defined under today's climate to future climates, as this assumes an un-acclimatized population and will produce overestimates of the impacts. Dessai (2003) assumed acclimatization to a 1 °C warming would occur every three decades. McMichael et al. (2004) indicate that acclimatization rates should be region- and scenario-specific to reflect the rate of warming experienced, and could thus be proportional to projected changes in average temperatures. Acclimatization can therefore be modeled simply as a shift in threshold temperatures, either for a fixed amount or linked to the changing climate in each region. The linear temperature-mortality relationships remain unchanged, assuming that populations acclimatize to their new average temperatures, but remain equally vulnerable to departures from average conditions (McMichael et al., 2004). However, it should be noted that, in reality, the shape or gradient of the slope might also change, as populations become less sensitive to temperature, perhaps through improved healthcare or living conditions.

An interesting approach to acclimatization is contained in the EU PESETA study (2009), where the threshold temperatures were shifted to reflect physiological and behavioral changes that can take place over the time-scale of decades. Using the rates suggested by Dessai (2003), PESETA assumed that the current temperature mortality functions applied to the baseline period (1961–90) climate and then shifted the thresholds by a *fixed rate* of 1.67 °C to apply to the period 2011–40 (central year 2025), and by 3.67 °C to apply to the period 2071–2100 (central year 2085). The same approach was used on the cold mortality thresholds. For the climate-dependent functions, acclimatization was introduced using an alternative method, reflecting the approach of McMichael et al (2004), using the 10th and 95th percentile thresholds in each grid cell based on the projected climate in the future time period under study. This assumes that populations acclimatize perfectly in step with the experienced rate of climate change. Since both the hot and cold thresholds are redefined, it also assumes that as populations acclimatize to the higher temperatures, they are less well-adapted to colder temperatures.

In the valuation of health impacts, there are three elements that need to be considered in estimating the total effect of the impact on society's welfare. These elements are:

- Resource costs i.e. medical costs;
- Opportunity costs i.e. the cost in terms of lost productivity, and
- The lost enjoyment of life by the diseased due to premature mortality plus the pain and suffering of loved ones.

Valuation of acute mortality focuses on the last element. That may seem like under-counting the true value, but it is not. First of all, economists assumed that the resource costs associated with each death would be incurred in any case when the individual dies. Also, because mortality effects from heat-related causes most often affects the elderly, it is assumed that they will be retired from the work-force so that element is also not included. This leaves just the loss in utility by the deceased person and loved ones.

Two metrics are currently used to measure this end-point: the value of a prevented fatality (VPF), also known as the Value of a Statistical Life (VSL)[33] and the value of a life year (VOLY), the latter providing a means of explicitly accommodating differing lengths of remaining life expectancy. Techniques have been developed to estimate the benefits in money terms of goods that do not have a market value, describing the 'willingness to pay' or the 'willingness to accept compensation' for a particular outcome. They include survey-based "stated" preference methods (contingent valuation, conjoint analysis, choice experiments) and "revealed" preferences methods (travel cost method, hedonic pricing). Stated preference methods can be obtained by constructing hypothetical markets and asking people via questionnaires and interviews what is their willingness-to-pay for a hypothetical change in risk (e.g. reducing the risk of dying in a given time period). The revealed preference method is based on observed choices actually made by people. These choices entail an implicit trade-off between money and risk (e.g. the wage levels for jobs that have a higher risk of fatal injury are higher than for those jobs with a lower risk). The latter method has produced the majority of VSL estimates; only recently has the stated preference technique been applied to estimate VSL or VOLY values.

There is considerable debate about whether current VSL and VOLY values are theoretically correct or accurate. Correct values should express accurately the willingness-to-pay (WTP) that individuals might express, e.g. to avoid an increase in mortality risks from climate change. More specifically, existing values are derived often in the context of the work-place (wage-risk studies) that estimate the willingness to accept (WTA) a higher wage rate in accordance with a greater risk of accidental death. Alternatively, attention has been given to the valuation of fatal transport accidents, the frequency of which might be expected to change with the introduction of new transport infrastructure.

33 The VSL is estimated by dividing the WTP (e.g. 50 Euro) for a given annual risk change, (e.g. 5 in 10,000), by the risk change. In this example, the VSL is equal to 100,000 EURO

Both the road and workplace examples of contexts differ from the climate change context and so may be expected to result in different WTP values. The principal differences are:

- **The length of life-time lost on average through the impact**. Whereas the impact of premature death in the road or work context can be expected to be on an individual of average age within the population and therefore result in the loss of about 35 years of life, climate change impacts are typically likely to lead to a loss of life of only a few weeks, months or years.
- **The magnitude of the risk change**. The differences between the two can be quite large: Assessments using VSL values are typically two to ten times higher than VOLY values when they are correctly applied.
- **Context specificity**. The nature of the risk is perceived to be different according to the degree to which exposure to the risk is voluntary, the extent to which the potential impact is perceived to be controllable, and the size of the impact (in terms of number of deaths resulting). For example, premature death as a result of a road accident may be perceived to be more voluntary to a death that results from climate change.

Recent studies have tried to address some of these issues. One of these is the EC-funded NEWEXT research project (Markandya et. al. 2004). This study used a contingent valuation stated preference technique and its results are particularly useful for our purpose since they are derived by pooling observations from three different EU countries. Values were derived from three surveys undertaken simultaneously in UK, France and Italy, using a common survey instrument. The survey instrument was designed to elicit WTP for mortality risk reductions. Specifically, people were asked to value an immediate 5 in 1000 risk reduction, (the risk change being spread over the next ten years) and an immediate 1 in 1000 risk reduction. While the policy area of direct interest to the study was air pollution, the agent for the risk reduction and the payment vehicle was in fact kept abstract in the survey design. The risk changes that were valued do, however, reflect the scale of risk changes thought to be likely from the introduction of a realistic new air pollution strategy in North America or Europe. Rabl (2003) derived the changes in remaining life expectancy associated with the 5 in 1000 risk change over a 10-year period, based on empirical life-tables. According to Rabl's calculations, the extension in life expectancy ranged from 0.64 to 2.02 months, depending on the person's age and gender, and averages 1.23 months (37 days). On this basis, one can compute the 3-country WTP estimates of VSL to life year equivalents and derive the corresponding VOLY. The estimates are presented in Table 6.1. The VSL value of 1,110 million € and the VOLY value of 59,000 € were used in the PESETA study to value temperature-related mortality.

Table 6.1 NewExt Results for 3-country pooled data
(Millions of € 2005)

	3-country pooled estimates	
	5:1000 risk change	1:1000 risk change
Value of Statistical Life (VSL)		
Median	**1.110**	0.840
Mean	2.280	3.140
Computed Value of One Life Year (VOLY)		
Median	**0.059**	0.038
Mean	0.133	0.143

6.2.2. Data Needs

The data needs for this type of analysis are best understood by looking at the steps in the analysis required to estimate the effects of climate change on temperature related mortality with the aid of Figure 6.4[34] The methodology included the following steps:

- **Re-grid and Aggregate Daily Climate Data (from Regional Climate Model).** Daily climate data must be geographically re-aligned to match the geographic coordinates of the socio-economic data (i.e., population, hospital admissions and deaths data at the sub-national level).
- **Calculate Parameters of Temperature Mortality Functions.** Computation of the temperature thresholds and slopes of the heat and cold wave mortality functions have to be carried out at the regridded sub-national scale for the population and climate data bases.
- **Scale Population Data.** The population data in each sub-national grid scale must be "scaled" temporally to account for economic growth and development in each cell. This will depend on the climate scenario being used.
- **Compute Percent Changes in Daily Mortality and Hospital Admissions.** The temperature mortality functions are applied to the daily climate data to estimate hospital admissions and deaths for each climate scenario in each grid cell. These outputs are then aggregated up to monthly or annual level depending on how detailed the study will be (for example if historical and current monthly death rate data is available).

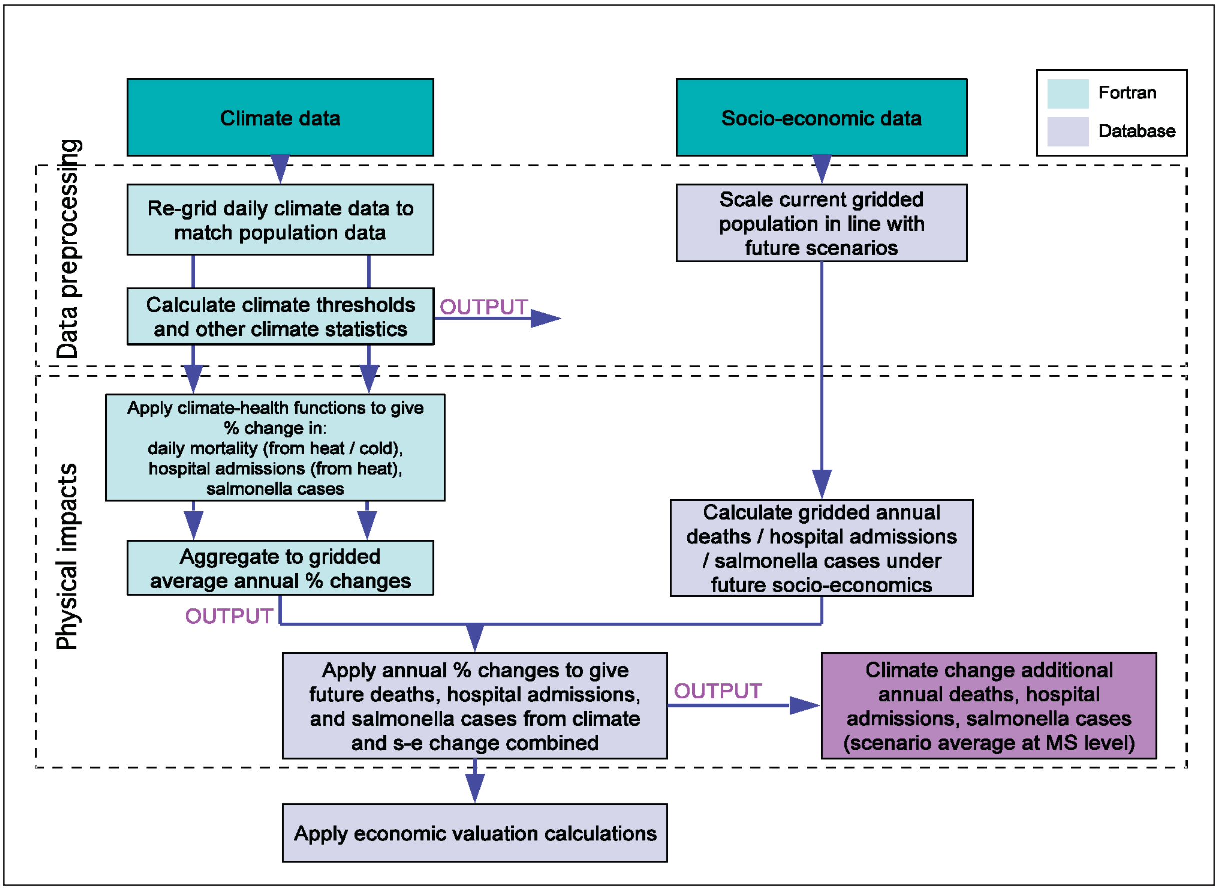


Figure 6.4 Overview of Physical and Economic Impact Modeling in the PESETA Project (PESETA, 2010)

34 Note that this figure from PESETA (2009) includes estimation of Salmonella deaths due to climate change.

6.3. Current Capacity to Estimate Temperature Related Mortality and the Associated Economic Losses in Montenegro

The methods for estimating the health impacts of climate change are not very different than estimating the health impacts of air pollutants. Empirical data are used to correlate historical variations in mortality and morbidity with the level of exposure to the air pollutant, just as in the case of the temperature mortality functions. Simulation models are used to transform the release of the precursor emissions from sources to receptor locations. This is much easier in the case of climate change, since GHG emissions from any single source have the same impact on global emissions concentrations. However, global and regional climate models are required to transform the GHG emissions into global, regional and local temperatures over time. Both global and regional climate change simulations exist for Montenegro. Therefore, all that is needed is to estimate temperature (heat and cold) mortality functions for the country and key cities, and then use the geographically gridded data in conjunction with the temperature mortality functions to estimate the temperature-related mortality in each grid. The VOLY and VSL used in the PESETA study can then be used to compute the value of climate change damages associated with changes in mortality due to the changes in temperature over time.

The only pieces of information that are lacking to do this at the current time are the temperature mortality functions for Montenegro and important cities. The data to do this are available: historical temperature daily temperature data and historical daily death records, using the epidemiological methods found in Kovats et al. (2006) and Baccini et al. (2008). All that remains is to organize these data, as was done for the PESETA study (See Figure 6.4).

The capacity to develop temperature mortality functions for Montenegro is within the grasp of epidemiologists in the country, although some specific training would be helpful to speed up the learning process. The job of estimating national, sub-national and city-specific temperature mortality functions would probably require something like a year of effort, depending on how well the national and city death data are organized. This subject was not explored, but could well be the biggest factor in determining how detailed the mortality functions can be on a geographic basis. As a first approximation, temperature mortality functions could be "transferred" from other locations, as was done in the PESETA study. The gridded climate data also exist, as does the capacity to develop and organize the requisite data bases required to use the complete PESETA methodology. However, this work has not been done and it is uncertain exactly how much additional effort would be required to do this, more likely a period of months instead of years.

Finally, it should be stressed that this study has only looked at the impacts climate change on temperature-related mortality. A number of other areas – vector borne disease, water and food borne disease (like Salmonella), the more general topic of infectious disease, and extreme events have not been covered, here. The analytical capacity to estimate these impacts and the climate change damages associated with them in Montenegro has not been investigated.

6.4. Preliminary Estimates of the Heat and Cold Temperature-Related Mortality due to Climate Change in Montenegro

The PESETA analysis was conducted using daily climate data simulations from a regional climate model over many sub-national grid cells in which the exposed population varied unevenly over time and space. It is well known that the smaller the temporal and spatial domains across which climate or weather data are being averaged, the greater the variation in the simulated weather or climate data. So, hourly, or daily or even weekly projections of temperature will be much more highly variable than will the monthly average temperature or the annual average temperature. However, given the time and resources available to the project, the only data that can be easily managed for this study are annual and monthly data.

Historical information about the variation in monthly and annual average temperatures was evaluated with the Country-Specific Bulgarian heat and cold temperature mortality functions (PESETA 2009) to arrive at Base Case Estimates of low and high temperature heat mortality. The threshold temperature for both functions (See Figure 6.3) is 17.7 degrees C; the slope of the cold temperature function is -0.7% change in mortality for every 1 degree increase in temperature, while the slope for the heat functions was 2.21% change for every 1 degree increase in temperature. The Base Case mortality rate estimates computed for Montenegro using the Bulgarian function were much lower (about ½) than those published for all countries in Southern Europe and the Balkan countries included in the PESETA. However, the differences between the published historical total mortality rates for these countries are much, much smaller. To simulate heat and cold waves, the historical distributions of monthly average temperature were supper-imposed on the seasonal average temperatures for the seasons (JFM, AMJ, JJA, SON) for each climate scenario A1BNF, A1BFF, A2BFF and the Bulgarian heat and cold mortality functions were used to convert the temperature information into mortality. But again, the low and high temperature variability in this data was much too small to capture the real variability in extreme temperatures. When the climate change mortality results were compared with countries in Southern Europe and the Balkans, they were one to two orders of magnitude smaller than the others.

Given that the problem encountered here is due to the lack of access of this project to existing (and maybe non-existing) data bases and resources to organize and manipulate the data, there is only one possible alternative to arrive at a first-cut estimate for temperature-related mortality and the economic value of the climate change damages associated with these additional deaths. The proposal involves assuming that the distributions of high and low temperatures deaths in both the Base Case and due to climate change are about the same for Montenegro as for Croatia (which used the Bulgarian temperature mortality functions). What differs between the two countries are the size of the population and the total death rate for all causes of death. If one can also accept the assumption that the Bulgarian country-specific temperature mortality functions are relevant for use in Montenegro (as was maintained in the PESETA study), then it would be possible to normalize the temperature mortality results arrived at for Croatia using the ratio of temperature mortality to total mortality and apply these ratios to Montenegro to estimate heat-related mortality in Montenegro.

These results of this analysis for heat mortality are shown in Table 6.2. Comparable estimates for cold wave mortality were not computed because these particular estimates are probably not very accurate, given the number of assumptions and the transfer of so much data from Bulgaria and Croatia to apply to Montenegro. It is assumed that the lessons learned from this exercise will also be transferable to the low temperature mortality.

Generally speaking the results follow the pattern in the PESETA study, as they should. Simulated heat mortality (due to climate change) increases in Montenegro for both the A2NF and A2FF scenarios, with the largest increase coming in the A2FF scenario[35]. This is expected since the temperature increases

35 The PESETA health study did not use the A1B NF or FF scenarios.

are higher in the FF than in the NF scenarios. These results are driven by the underlying direction and variation of the temperature fluctuations in the climate scenarios used in the PESETA study. These temperature data are on a much finer grid scale and shorter time scale than the published climate scenario data available from Montenegro. Furthermore, because the A2NF scenario was not included in the National Communication of Montenegro (2010) and the A1BNF scenario was not included in the PESETA health study, it is not possible to give a better explanation for these differences. However, it is likely that the localized changes in heat-related mortality will vary widely under climate change as is probably the case, historically, in Montenegro. This study would have benefited from a closer examination of heat-related mortality in Podgorica. However, existing published data do not make it possible to estimate a temperature mortality function for Podgorica.

Table 6.2 Average Annual High Temperature Mortality and Future Value of Mortality Estimated for Croatia and Montenegro for the A2NF and A2FF climate Scenarios, Assuming Croatian Climate and Heat Mortality Normalized to Lower Montenegro Mortality Rates in the Base Case and No Acclimatization

Country	Average Population	All Deaths Base Case	Heat Related Deaths Base Case	Heat Re-lated Deaths A2NF	A2NF VOLY-VSL (Million €)	Heat Re-lated Deaths A2FF	A2FF VOLY-VSL (Million €)
Croatia	4,535,330	66511	1042	1728	16.3 to 754.4	2,499	86 to 1,603
Montenegro	550,210	3535	55	92	7.1 to 40.1	127	4.6 to 85.2

Estimates computed based on Croatia results for country specific temperature mortality in functions in PESETA (2009), and data bases and Statistical Year Books for Croatia (2009) and Montenegro (2009). Heat-related deaths adjusted for differences in historical and PE-SETA death rates.

There are three important, but very tentative, conclusions that can be drawn from these attempts to quantify the effects of climate change on temperature-related mortality and the climate change damages associated with these impacts. The first is that some of the same factors that contribute to Montenegro's relatively low death rate (at least compared to Croatia's), will probably not go away when the climate changes, but will continue to help to insulate the population from the dangers of high temperatures. Second, these mortality estimates would be far lower (at least 50 to 75% lower based on the PESETA study) had acclimatization been included in the analysis. The reason for not including it is that to do so requires data bases that were not available to the study to review, manipulate and organize. Finally, the relatively large future (undiscounted) economic values (VOLY and VSL) associated with the mortality estimates are due simply to the fact that, when you multiply a large number by even a small number you can still get a relatively large number. Valuation of life is a controversial topic, both for the methods used to obtain these values and with regard to how such estimates should be used to make policy choices.

6.5. The way Forward in Human Health

As stated in the introduction to this study, the coverage of the economic impacts of climate change on human health is limited to temperature-related to mortality, only. As such, this chapter did not do an in-depth investigation of the capacity in the country to assess the physical or economic dimensions of climate-related impacts on human health. In addition, very little of the applied work in the area of climate change is about economics. Rather, the climate-health impact studies are very largely epidemiological studies and the VOLY or VSL estimates are "transferred" to the mortality estimates. The cost of non-fatal health impacts are calculated differently by methods that were not discussed here. Application of these methods can rely on local data, but often the economic values are transferred from other studies about similar health impacts.

6.5.1. Main Findings (Temperature-related mortality only)

- The data to estimate the parameters of cold- and heat-related mortality functions for Montenegro and important cities probably exist, but may not be easy to access or organize.
- Statistical epidemiology is not a highly developed field in Montenegro, but the education and training to estimate heat- and cold- mortality functions is fairly basic

6.5.2. Main Recommendations (Temperature-related mortality only)

- Short-Term (Next Few Years):
  - In concert with national health institutions and organizations, undertake a project to organize existing mortality and population data to estimate cold- and heat-related mortality nationally and in key cities, using disaggregated weather and mortality data.
  - In concert with national health institutions and organizations, undertake to estimate cold- and heat-related mortality functions nationally and for key cities and simulate the impacts of projected changes in climate, taking into account various forms of acclimatization.
- Long-Term (Five – Ten Years)
  - In concert with EU-wide assessments of the health impacts of climate change, expand the capacity to cover other health impacts that may be related to climate change.

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